STOCKPILE AND ACCESSIBILITY OF STRATEGIC AND CRITICAL MATERIALS TO THE UNITED STATES IN TIME OF WAR

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON MINERALS, MATERIALS AND FUELS ECONOMICS

OF THE

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS UNITED STATES SENATE

EIGHTY-THIRD CONGRESS

SECOND SESSION

PURSUANT TO

S. Res. 143 and S. Res. 271

RESOLUTIONS TO INVESTIGATE THE ACCESSIBILITY AND AVAILABILITY OF SUPPLIES OF CRITICAL RAW MATERIALS

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PART 11

Synthesis, Substitutions, and Replacements of Scarce Strategic Materials

SEPTEMBER 21, 22, OCTOBER 25, NOVEMBER 17 AND 18, 1954

Printed for the use of the Committee on Interior and Insular Affairs

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STOCKPILE AND ACCESSIBILITY OF STRATEGIC AND CRITICAL MATERIALS TO THE UNITED STATES IN TIME OF WAR

TUESDAY, SEPTEMBER 21, 1954

UNITED STATES SENATE,
MINERALS, MATERIALS, AND FUELS ECONOMIC SUBCOMMITTEE
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
San Francisco, Calif.

The subcommittee met at 10 a. m., pursuant to notice, in room 261, Federal Courthouse and Post Office Building, San Francisco, Calif., Senator George W. Malone (chairman) presiding.

Present: Senator George W. Malone (chairman).

Also present: Jerome S. Adlerman, chief counsel of the subcommittee, and George B. Holderer, staff engineer.

Senator MALONE. The subcommittee will be in order. On July 27, 1953, the Senate of the United States passed a resolution, Resolution 143, directing the committee of which I have the honor of being chairman to make an investigation and a report on the availability of the critical materials to this Nation in wartime and for our expanding economy and our security.

A condensed copy of the resolution I will submit for the record at this point.

[S. Res. 143, 83d Cong., 1st sess.]

RESOLUTION

Resolved, That the Senate Committee on Interior and Insular Affairs, or any duly authorized subcommittee thereof, is authorized and directed—

(1) to make a full and complete investigation and study of the accessibility of critical raw materials to the United States during a time of war;

(2) to study and recommend methods of encouraging developments to assure the availability of supplies of such critical raw materials adequate for the expanding economy and the security of the United States;

(3) to report to the Senate at the earliest possible date, not later than January 31, 1954, the results of its investigation and study, together with its recommendations.

Senator MALONE. On July 9, 1954, after investigations over a period of approximately 1 year, I submitted to the United States Senate a report of the Committee on Interior and Insular Affairs, made by its Minerals, Materials, and Fuels Economic Subcommittee, pursuant to Resolution 143, a resolution to investigate the accessibility and availability of supplies of critical materials to this Nation in time of war, and for its expanding economy and for its security. That report number is 1627, entitled "Accessibility of Strategic and Critical Materials to the United States in Time of War and for Our Expanding Economy."

The report itself is a digest of the 10 volumes of public testimony, where we heard approximately 360 witnesses, starting, as a matter of fact, in Seattle last September, also at the meeting of the American Mining Congress. We like to coincide our hearings with the American Mining Congress meetings because many engineers and producers attend these meetings, and it saves the committee the expense of traveling to other centers where these men are located, or having them come all the way to Washington.

Now, this report with its introduction, 12 recommendations, and its 14 findings covers the entire subject. The remainder of the report of approximately 400 pages, consists of supporting data, and a digest of these 10 volumes of published testimony.

Now, the committee determined in the course of its work, after hearing Generals Wedemeyer, Bonner Fellers, Major de Seversky, and Gen. "Tooey" Spaatz, and then in executive session with Mr. Wilson, who is Director of National Defense, together with his entourage, that the Western Hemisphere can be defended. As a matter of fact, it is the only area that can be defended according to these outstanding military strategists, in the first go-around of world war III or IV, whatever it is determined to be, depending on whether you call Korea a war or just a police action.

It was necessary for this committee to determine the area that could be defended and be available in time of war because the resolution directed that we do just that. So then, starting with the Western Hemisphere, testimony by these men shows that it will be the only dependable—"dependable" is the word most of them use—supply during the third all-out war. Hours or days after war starts, all offshore areas across major oceans would be unavailable; that is, supplies from offshore areas would be unavailable to the United States until we had started to win the war and again controlled the air over these areas, whether it be Africa, Europe or Asia.

The committee then determined, after hearing these outstanding operators, producers and engineers—and this includes Government engineers and economists, the Bureau of Mines, the Department of Agriculture, State Department, Department of Commerce—that the Western Hemisphere could be made self-sufficient in the production of all of these materials, critical materials, considering substitutes and replacements which of course are continually being discovered, new materials that take the place of old. It was determined that there were 77 such critical materials, named by the National Defense Organization.

Our laboratory work is one of the most important parts of any such investigation and determination.

Now, at this point in the record, I want to include the 12 recommendations that the committee made, which are as follows:

COMMITTEE RECOMMENDATIONS

"The availability of critical and strategic materials are vital to military security and to an expanding domestic economy. National survival in time of war depends on ample and uninterrupted supplies of the 77 such materials included in the report. To assure that imperative needs of the United States be met:

1. We recommend the closest cooperation among the nations of the Western Hemisphere, which is the only dependable source of the necessary critical materials in time of war. This area can be defended and can be made self-sufficient

in the production of such materials. We recommend that the spirit of the 130-year-old Monroe Doctrine prevail in our relations with the nations of the Western Hemisphere.

2. We recommend that Congress insure that the regulation of foreign trade conforms to the principles thus laid down in article I, section 8, of the Constitution thus assuring the American workers and investors equal access to American markets.

3. We recommend eliminating our Nation's present dependency upon remote and possibly unfriendly or neutral areas of the world for the critical materials, without which we cannot conduct a war.

The only tin smelter in the Western Hemisphere is in Texas City, Tex. The continued operation and maintenance of this smelter is essential to our security. The capacity meets our wartime needs.

4. We recommend increased depletion allowances to producers of critical minerals and materials as a further incentive to production.

Further studies should be made of the Canadian method of delayed taxation in connection with such critical mineral and material development.

5. We recommend acceleration of the Federal program of stockpiling critical and strategic minerals and materials to assure ready supplies in the event of war and coordination of this program with "going concern" production industries in the Western Hemisphere to assure continuation of necessary supplies under stress of war.

6. We recommend studies with a view to improve petroleum, gas, and coal resources and develop them to assure maximum availability of domestic fuels for both the peacetime economy and national security. Such studies should determine whether present regulations are unduly restrictive of our own resource expansion and reserves, and if so, regulations should be adjusted to maintain our self-sufficiency in these vital fuels.

7. We recommend increasing the production goal for titanium to 150,000 tons annual minimum without delay. Titanium is a new wonder metal. This is a military must. Contracts should be awarded without delay by the Government to qualified concerns prepared to contribute toward this goal. Civilian demands are tremendous for this heat-resistant high-strength-weight-ratio, noncorrosive, nonmagnetic metal.

This metal can become the basis for a 5- to 10-billion-dollar new civilian industry. Production of the long-range supersonic speed bombers and the necessary fighter planes will make obsolete any nation's air equipment built without it.

8. We recommend that goals for production of uranium for fuel be made adequate to meet both military and civilian requirement. Hemisphere self-sufficiency in uranium for fuels can be attained. A liberal long-range market price must be maintained as long as Governnnent control is necessary for security. A tremendous civilian potential use of uranium is assured based on nuclear power for industry.

9. We recommend a review of the work of the Securities and Exchange Commission by the appropriate committees of Congress to clarify its duties and responsibilities. The sale of securities affects the strategic materials program. It is recognized that the Commission should assure full and complete information to potential purchasers of securities, and that its responsibility does not include determination of feasibility. Such congressional committee review should consider the advisability of a requirement that a thorough and confidential inquiry should precede any public announcement of an investigation of offered securities.

10. We recommend determination by the Congress, through appropriate committees, of the precise duties and relationships between the multiple (approximately 38) agencies and branches of our Government responsible for stockpiling operations of critical materials.

The determination of these duties should precede the appropriation of funds for these agencies with the aim of facilitating their work and of fixing responsibility for the proper coordinated objectives.

11. We recommend appropriations of $50 million annually to establish and operate a comprehensive 5-year program of laboratory, pilot-plant, and exploratory research into improved methods of beneficiation of critical materials and the study of substitutes, including synthetics and replacements.

We approve the research and studies conducted by the Bureau of Mines on the low-temperature carbonization of coal and we recommend that adequate funds be appropriated to conduct extensive studies and investigations of ways and means to revive the coal industry. These funds should be made available to be used

independently or in conjunction with responsible privately operated companies and organizations.

It is recommended that research and pilot-plant work be continued. That the erection of a large-scale oil-shale plant be considered by industry in cooperation with the Government. Such plant would endeavor to advance the production of petroleum fuel on a commercial basis, and it would be available in a war emergency.

12. We recommend rejection of international controls of production, prices, and supplies of critical and strategic materials unless by legislative action by the Congress of the United States.

The hearings in San Francisco at this time are in conformance with Senate Resolution 271, passed by the 2d session of the 83d Congress, to continue the work of the committee, and that is the authority under which the committee is operating at this time.

(The resolution referred to follows:)

[S. Res. 271, 83d Cong., 2d sess.]

RESOLUTION

Resolved, That the Senate Committee on Interior and Insular Affairs, or any duly authorized subcommittee thereof, is authorized and directed (1) to (continue) investigate and study the accessibility of critical raw materials to the United States in time of war and for the expanding economy in time of peace; (2) to make a full and complete investigation and study of new developments and discovery of materials including synthetics which may be used as substitutes and replacements of critical materials, and further to study the progress of research programs, pilot-plant operations, processing and beneficiating methods of critical materials and minerals including fuels; (3) to make a full and complete investigation and study of the best means, methods, and devices to foster the greatest measure of self-sufficiency of critical materials that can be produced within the United States and the Western Hemisphere and to expand and develop the strategic materials industry; (4) to make a full and complete investigation, and study the status of the stockpile program, its goals, methods, and amounts of acquisition, storage, warehousing, and rotation programs; (5) to make a full and complete investigation and study the available fuel reserves of the United States and the Government regulations affecting such resources and to formulate and recommend a national fuel policy to assure maximum availability to meet the needs of the peacetime economy and for the national security in time of war; and (6) to report to the Senate at the earliest possible date, not later than January 31, 1955, the results of its investigation and study, together with its recommendations.

SEC. 2. For the purposes of this resolution, the committee, or any duly authorized subcommittee thereof, is authorized to employ upon a temporary basis such technical, clerical, and other assistants as it deems advisable, and is authorized, with the consent of the head of the department or agency concerned, to utilize the reimbursable services, information, facilities and personnel of any of the departments or agencies of the Government, or of qualified private organizations and individuals. The expenses of the committee under this resolution, which shall not exceed $34,000, together with any unexpended balances remaining from the authority of S. Res. 143, agreed to July 20, 1953, and S. Res. 171, agreed to January 26, 1954, shall be paid from the contingent fund of the Senate upon vouchers approved by the chairman of the committee for obligations incurred during the period July 1, 1954, to January 31, 1955, inclusive.

Senator MALONE. It is the intention of the committee to continue the work, but to visit each of the South American nations, including a part of the Central American area and Mexico.

The committee also determined, in addition to the fact that the Western Hemisphere could be made self-sufficient in production of all of these critical materials, and not as we have been led to believe over 35 or 36 years that we had to defend offshore nations, across major oceans; we determined and so recommended that under proper policies laid down by the Congress of the United States, proper prin-

ciples, that the United States proper could increase and would increase its production materially of many of these materials; but a principle must be established by Congress and not left to the whims of a bureau official.

Now, the Constitution of the United States, article I, section 8, says that the legislative branch, the Congress, shall regulate foreign commerce, foreign trade, and shall set the duties, imposts, and excises that we have come to regard as tariffs, and import fees. But, in 1934, there was an act passed by Congress, a little noticed act, that amended the Constitution of the United States without submission to the States or to the people of the United States, which transferred the responsibility of regulating foreign trade through an adjustment of the duties or tariffs to the executive department. The executive department, without further ado, transferred the responsibility to the State Department, which has been busily engaged for the last two decades in dividing the markets of the United States with the sweatshop labor countries of the world, through the simple expedient of making agreements to lower tariffs, or duties as the Constitution calls them.

They are not really trade agreements; that is, they make agreements to lower duties without regard to that differential cost of production represented by the difference in the wages, taxes, and other costs of doing business, effective wages, "effective" meaning the efficiency of the labor. They have no thought of that difference, but their thought is to divide the market.

Now, the 1934 Trade Agreements Act was passed in 1934, on June 12, for 3 years; it was extended for 3 years without change for a considerable time, every 3 years. Then in 1951 the act was amended to include a provision that allowed the Tariff Commission to determine what might be called a peril point, a point at which an industry would be imperiled. They had no authority to make effective such a determination, but could submit it to the Executive.

Then there was an escape clause, a so-called escape clause, which, of course, was never effective—no one ever escaped of any consequence. A peril point means nothing, because a peril point today might not be the same tomorrow, due to manipulation of currency—the trade advantage of these foreign nations—and to changing economic conditions. Nearly every nation, including our own, is printing money and bringing on inflation. It is a question of the degree and how fast.

In 1951, we extended the Trade Agreements Act for 2 years. We cut it to 2 years and included some amendments. In 1933, it was extended for 1 year, and in 1954, 1 year. It now expires at midnight on June 12, 1955.

Many organizations have passed resolutions that it should be allowed to expire and revert to the Tariff Commission, an agent of Congress. Then the Tariff Commission could determine that difference of cost of production and recommend that it become the tariff, on a flexible basis. That is the law of the land now, superseded, of course, by the 1934 Trade Agreements Act, as extended.

There was a reason, of course, for the Constitution providing that the legislative branch adjust the duties or tariffs and the regulation of foreign commerce, because every precinct in the United States, every State in the Union, is represented on the House and Senate floor. The State Department, to which was delegated the authority to adjust the duties or tariffs, have their eyes on foreign countries,

trading the market of the United States for some fancied foreign advantage, which it now develops that they do not get. Nevertheless these agreements have been made, they are in full force and effect, and if this act is not extended, it then reverts to the Congress, as already indicated, as provided for by the Constitution. The trade agreements, then, remain in full force and effect until the President of the United States serves a notice of cancellation on the countries with which such agreements have been made. This he can do at any time.

Then we are back in business, according to most of the representatives of the business of this Nation, not only including minerals but crockery, clothespins, precision instruments, motorcycles, and 500 other products.

Now, this morning we have a well-known and prominent individual appearing before the committee. He is the president of the American Mining Congress, and the committee is very much interested in his reaction to the work of the committee.

Howard, would you identify yourself for the committee and make any statement that you care to make in regard to the work of the American Mining Congress, and your own individual reaction as to how best to regulate foreign trade and to adjust the duties or tariffs in relation to the production of the American workingman and the American investor. We are very much interested in your reaction to this whole thing.

STATEMENT OF HOWARD I. YOUNG, PRESIDENT, AMERICAN ZINC, LEAD & SMELTING CO., ST. LOUIS, MO., AND PRESIDENT OF THE AMERICAN MINING CONGRESS

Mr. YOUNG. Well, Senator, my name is Howard I. Young. I am president of the American Zinc, Lead & Smelting Co., St. Louis. I am also president of the American Mining Congress of Washington, which represents all branches of the metal and nonmetallic mining industry throughout the United States, including bituminous and anthracite coal and the cement industry. I want to make my statement, Senator, on the basis of my personal feeling in this situation, going back to the time that this legislation was originally proposed in 1934. I believe it was the year I represented the National Association of Manufacturers in appearing before the Ways and Means Committee in opposition to the Reciprocal Trade Act.

1934 TRADE AGREEMENTS

Senator MALONE. You mean the 1934 Trade Agreements Act, that was named "reciprocal trade"?

Mr. YOUNG. That's right.

Senator MALONE. You are also aware that the phrase "reciprocal trade" does not occur in the act at all?

Mr. YOUNG. Certainly, my experience and observations have been, that the Trade Act, while it may be in theory a good piece of legislation, it has only been operated as a one-way street in favor of those who import, and does not protect the American industry and workmen to the extent that we must be protected if we are going to continue to develop and advance our economy and industrial activities as I think we should.

Senator MALONE. Did you ever find anything reciprocal about it?

Mr. YOUNG. I have not. I have talked with Cordell Hull, who was Secretary of State, the "daddy" of it, quite extensively, and he would always assure us that this was going to be done and that was going to be done, but our observation is that the escape clause in the bill that was supposed to protect American industry has only been used, that I know of, on three occasions. One of them was on the importation of furs from Canada; the other was on the importation of lace handkerchiefs, I believe from France or one of the European countries, and the other was recently on the basis of the Swiss watch situation.

Senator MALONE. Yes.

Mr. YOUNG. That was done entirely on account of the recommendation of the Defense Department, I understand.

Senator MALONE. Well, Howard, I am very much interested in your statement. Isn't one of the weaknesses, perhaps, of the whole situation that the State Department, representing the executive department, is the sole judge of whether they let anyone escape or not, and their whole objective has been to divide the markets and not to protect the domestic investors or workingmen at all.

DISCOURAGING DOMESTIC MINERAL INDUSTRY

Mr. YOUNG. That has been the experience to date, Senator, going back to before the second European war, going back to the first time that they made some substantial reductions on the duty on zinc and lead into this country, while the Secretary of State would try to assure you that you were not going to be hurt when he referred you to the people who are really dictating the policy program for the Secretary of State and the Executive Department to act upon, they didn't carry out that policy to any degree at all that I know of. While I am firmly convinced that we want to have a proper type of foreign trade relations, certainly we do not at this time have a setup that is giving, in my judgment, the proper consideration to the future development of the natural resources of this country, and a continuation of the policy that has been followed recently is going to discourage the investment of money in developing our domestic resources today.

I might say this, Senator, that in our own company we have no production or development outside of the United States. We have investigated foreign mineral resources from time to time and one of the points that those of us who are recommending and trying to develop our domestic natural resources meet, in discussing the money that is necessary to put in development, with our board of directors, they say, "Well, now, what assurance have you that we are going to have even the tariff protection that we have today, in view of the present attitude of the administration, that today has the final word on the question?"

The last "go-around" I will call it, on lead and zinc was a decided disappointment to all of us in the mineral industry.

Senator MALONE. Well, didn't Congress just vote to extend it the way it is; I mean, without any opposition to it?

Mr. YOUNG. Unfortunately they did, and we think—I might say this just so you will know my own personal opinion—I have always, from a national standpoint, been a Republican. I am a strong Republican. My basic reason for being a Republican is that I felt that

American industry, even though we have all the advanced technique and all the things that we have in this country, that the American industry must have certain tariff protection if we are going to continue to grow as we should grow.

Senator MALONE. Well, now, I am very much interested in that statement, for the very reason that every time anyone mentions a tariff some "one world" columnist, or "one economic world" papers and periodicals immediately jump down his throat, saying that he wants a higher tariff, or he wants to build a wall around the United States. Now, no one of my acquaintance has ever mentioned any wall or ever mentioned any high tariff. They have many times mentioned—and I think the junior Senator from Nevada has been preaching it for 25 years—that what we do want is the authority in the Congress, just as the Constitution says, put it where the Constitution puts it. Congress created a Tariff Commission as their agent to determine on a basis of fair and reasonable competition what the duty or tariff should be, meaning that that duty or tariff would make up that differential in the effective wages, effective wages meaning any difference in efficiency, taxes and other costs of doing business in this country as compared to the cost of doing business in the chief competitive nation in each particular project.

Isn't that about what you mean by a protection of the American investor and workingman?

Mr. YOUNG. That is all I mean. It is just a reasonable tariff.

Senator MALONE. Well, reasonable as based on facts?

Mr. YOUNG. That's right, based on facts.

Senator MALONE. Difference in costs.

Mr. YOUNG. Let's just take the last experience, where I think the most complete investigation that has ever been made by any Government commission was made by the Tariff Commission in connection with their study on zinc and lead, and my understanding is that the Commission, which is composed of both Democrats and Republicans, were 100 percent in favor of the report and the recommendation went out with only 1 dissenting vote. Such dissenting vote was on the basis that the tariff on zinc and lead should not be increased above the basic rate that was established when the tariff was put on a number of years ago, as against a recommendation by the balance of the Commission for a duty 50 percent above that in effect on January 1, 1945, and that report was not given the consideration, in our judgment, that it should have been given.

Senator MALONE. Well, then, Howard, why would we say that we won't want it increased above what had been established on a prior date, without any knowledge or investigation to determine what that difference in the cost of production, brought about by the increased—that is, not the increased but the prevailing wages, wage standard of living here, taxes, and other costs of doing business, as compared to the same items in the chief competitive nation; in other words, over a period of 22 years we say that our dollar is a 53 percent dollar. I recall, however, and I am about to investigate that matter as we bring it out in the open, that sometime around 1946, they changed the method of comparison and put the comparison on the basis of 1938 instead of 1932. On a basis of 1932 the purchasing power of the dollar is about 34 cents, I think.

Mr. YOUNG. Yes.

Senator MALONE. But in any case it has been materially decreased. Now, you are one of the most experienced industrialists in the United States of America. People regard your judgment very highly, because you have made a success of the business, and I think one of the things that happened to this country, we started to listen to these hand-raised economists talking about what should happen when everybody is trading with everybody else, without any adjustments on the standard-of-living costs at all. That's what's the matter with the United States now. These men, these hand-raised economists, who have never been in business, learn about the economy of this country by reading books, whereas you have to meet a payroll.

Mr. YOUNG. That's right.

Senator MALONE. And every other mining organization in the United States of America, and that isn't confined to mining at all, every business in America—if they miss a payroll a couple of months, they are in somebody else's hands.

These hand-raised economists, when they miss a payroll they simply appropriate more money and go out and squeeze it out of these little taxpayers all over the country, and they think that is a good way of doing business.

PROCEDURE FOR PROTECTING DOMESTIC INDUSTRY

But now, to get back to the tariff, any fixed tariff as compared to a flexible one—and most of the tariffs or duties are fixed, like, for example, on zinc, or lead, or any other commodity. Say, for example, a commodity had a 10-cent-a-pound tariff when the product was selling at a dollar a pound. That would be a 10 percent tariff or duty. Now, in that fixed tariff, 10 cents is still 10 cents when the product is selling for a dollar and a half, or we will say $2, for purposes of illustration. It's a 5-percent tariff.

Mr. YOUNG. That's right.

Senator MALONE. In other words, why do you then say that you shouldn't adjust the original duty or tariff in accordance with the inflation and the cost, as compared to the cost of the chief competing country in any particular product, the whole 5,000 of them that are produced in this country, or 10,000, whatever it is; why do you refer back to the original duty at all?

Mr. YOUNG. In making that statement, Senator, it was my understanding that one member of the Tariff Commission, only one member of the group, thought that they shouldn't go above the original rate of $1.75 per pound.

Senator MALONE. What was the reason for that?

Mr. YOUNG. I don't know.

Senator MALONE. A political reason?

Mr. YOUNG. I don't know, but you are absolutely right in the illustration you have just made. You take now where we have a seven-tenths of 1 cent per pound duty on the importation of slab zinc, we should have the duty that a majority of the Tariff Commission voted for, which would bring it up to around a little over 2 cents per pound. Now, on the other hand, I think, and I believe most of the industry agree, that when we have the price of zinc and lead up to a certain level here, that above that price level the tariff shouldn't be so great.

Senator MALONE. Just let me ask you one more question in that regard; I have read all these trick formulas about if the tariff, or if the pricing goes to a certain point, the tariff is reduced and so on. Why not leave it in the hands of the Tariff Commission on a flexible basis? In other words, if the tariffs were fixed at 2 cents at this moment, a further manipulation of foreign currencies could fix it so it would be ineffective, would it not?

Mr. YOUNG. Sure, absolutely.

Senator MALONE. Well then, why not give it to the Tariff Commission? Let them, on their own notice, on request of a congressional committee, or on a request of a producer call a new set of hearings, and on the new basis adjust for any manipulation in currency in this chief competitive nation or any change in costs whatsoever. Why go into all of the throes of setting a certain price; this certain price that you select may be entirely erroneous in 6 months.

Mr. YOUNG. That is quite true. We have seen it in the last year.

Senator MALONE. Well, why do we go into all that?

Mr. YOUNG. Well, the only reason that we go into all of that, or have gone into that——

Senator MALONE (interposing). Because you don't think you can get anything else; is that it?

Mr. YOUNG. Because we feel that there has been a certain precedent established on that basis, that if we could have it in our industry it would be much better than what we have been able to get so far.

Senator MALONE. You would just have a better chance to survive. Now, as you know, Mexico devalued 40 percent since the first of this year. What would that have done to the 2-cent tariff, cut it 40 percent, wouldn't it?

Mr. YOUNG. Absolutely, no question about that.

There is one thing you have to take into account on that, Senator, and that is in talking with Mexican operators we found that as soon as that happened the Mexican Government immediately raised their export tax, so as to get more money into the government till, but we do nothing.

Senator MALONE. All right. Then why not allow the Tariff Commission, an agent of Congress made up of fine, experienced men, why not leave the authority in their hands to adjust for any of these matters?

Mr. YOUNG. I am strong for it; we are. When I say "we are," there is no one, as you know, that can speak for a big industry and say it is a hundred percent for this, that, and something else, but the majority of the people who are producers in the United States would be very happy indeed to see it put in the hands of the Tariff Commission to make recommendations to Congress for the congressional approval of those recommendations.

Senator MALONE. Why has Congress approved them? This is suggested, that Congress leave it to the Tariff Commission to continually adjust on a flexible basis the duty or tariff on every one of these five or ten thousand products that are being produced or could be produced economically in the United States of America. Then, if Congress doesn't take action specifically against a recommendation that they make within a limited time of 60 days—we have a precedent for that—why, it automatically becomes effective.

Mr. YOUNG. Well, that probably would be better than the suggestion that we—when I say "we" now, that the American Mining Congress have thought was the right one to adopt, which was to place this in the hands of the Tariff Commission with Congress having the final approval, instead of the Executive Department.

Senator MALONE. Yes, or the refusal or whatever it might be?

Mr. YOUNG. That's right.

Senator MALONE. Why then, I am going to ask you the direct question: Why doesn't the American Mining Congress simply recommend to the Congress of the United States that they do not extend this, really, a free trade——

Mr. YOUNG (interposing). Reciprocal.

Senator MALONE. I am unable to find the words "reciprocal trade" anywhere in connection with the act, except through the mouthings of the New Deal columnists and the people who follow this thing on a world economic basis. There is no such phrase in any of the laws. The words have never been mentioned except to the very people who are promoting you out of business; so I say, why doesn't your organization just recommend that Congress sit still, just sit still and don't pass anything, and allow it automatically to revert to the Tariff Commission, on the basis that we have just described; it's in the law now.

Mr. YOUNG. Well, they may decide to do that before the next Congress meets. I can't say whether they will or will not.

Senator MALONE. What is the matter with their meeting here? They are meeting here 4 days or 5, all week. We have come down and brought the committee staff 3,000 miles to determine what their thoughts are and what the thoughts are of the outstanding producers and engineers, such as yourself.

Mr. YOUNG. Well, it seems to us who have considered this question that we should strongly recommend that the fixing of tariffs, as reported by the Tariff Commission, should be taken out of the hands of the Executive Department and placed in the hands of the Congress.

Senator MALONE. You don't have to take it out, if you just sit still it goes out. Why don't you ask them to just sit still and not extend the thing?

Mr. YOUNG. Well, isn't it better, Senator, to——

Senator MALONE (interposing). No, you can't take it out, you can just sit still and let it fall out, if that's what you would like to have; it will then just automatically revert.

Mr. YOUNG. You know much more about the legislation than I do, but we certainly want it taken out of the handling, as it is today, and maybe your suggestion is the best one.

Senator MALONE. Well, do you understand that if Congress just sits still past midnight on June the 12th, 1955, and does not pass anything at all, that it reverts to the Tariff Commission, an agent of the Congress, on the basis that we have just described?

Mr. YOUNG. I think you are right. That goes back to the old law, then, doesn't it?

Senator MALONE. Well, what is the old law; the old law says specifically that the Tariff Commission shall determine the difference in cost and shall recommend the tariff. It doesn't give them any leeway to give anybody anything, to give some part of an industry to a

foreign nation at all. It simply puts it on the basis of fair and reasonable competition. Isn't that what you want?

Mr. YOUNG. Definitely. That is not only what we want, it is what we have got to have if we are going to develop the resources of this country as we should.

The President has come out, even since the Congress has adjourned, and since Denver, in a letter to Mr. Bullis of the General Mills Co., assuring him that that is one of the first things that Congress is going to consider. As you know, on this foreign trade business we thought—now, we may be mistaken—we thought that the resolution, or think that the resolution that we are recommending here to the meeting is the one that would receive the best consideration from you and other Members of the Senate and the House of Representatives who have the responsibility of passing whatever legislation is the proper legislation for our foreign trade.

Senator MALONE. Well, you do not want Congress to pass anything, you have already testified to that; just let it revert to the Tariff Commission—an agent of Congress—to adjust duties or tariff on the basis of fair and reasonable competition.

The President of the United States, or 1 Member of the Senate, or even all of the Members of the Senate, or 1 Member of the House, or all the Members of the House, do not make national policy. That ought to be recognized by this time in the United States of America. The Constitution provides for three branches of government. There has been some doubt about it in the last two decades. We had a Congress, a legislative branch that passed the laws of the country; we had an Executive who carried them out. He is an administrator, he is an executive, just what you are to your company. If the board of directors overrule you in something, you carry out what the board of directors directs you to do. Then the judicial branch was to pass on constitutional and other questions.

Mr. YOUNG. That's right.

Senator MALONE. You are president of your company?

Mr. YOUNG. That's right.

Senator MALONE. Like Mr. Eisenhower is President of the United States; and we have the highest regard in the world for him, but the executive branch of the Government in the original concept of government was not dominant over the legislative branch or vice versa, and neither was it to dominate the judicial branch. You have 3 branches, you had 3 branches. I hope to God we can maintain those three branches.

Now, the President of the United States, then, doesn't make foreign trade policy according to the Constitution. Article 1, section 8, definitely puts that responsibility on Congress; the junior Senator from Nevada doesn't make foreign trade policy. We can each have our ideas about it and make them known to the Congress of the United States, and we each have at different times.

You will remember the Randall report. The Randall report was cooked up to give the people of the country the story of building up our foreign allies through trade. So what did he recommend; he recommended a 15-percent further reduction in tariffs or duties over a 3-year period. He recommended that we give the foreign nations a large amount of money, it runs in my mind $5 billion, to stabilize

their currency, and extend the 1934 Trade Agreements Act for 3 years. Just what became of Mr. Randall after he rendered his report is not entirely clear to all of us in Congress. We haven't heard much out of him for a while. Certainly his recommendations were not taken, but they were able to compromise on a 1-year extension of the act, 1934 Trade Agreements Act. It now expires at midnight, June 12, 1955, and that could be a very momentous date for American industry.

Now, the President has said that he would like Congress to take this matter up, but when he makes a positive statement that will be the first thing they consider, I think he could be mistaken.

Mr. YOUNG. I think so, too.

Senator MALONE. Now, I am a member of the Senate Finance Committee. There are 15 members of the Senate Finance Committee, to which will be referred any legislation introduced by any Senator. The President can't introduce legislation, but he could probably get it introduced by some Senator, then come to our committee. I will guarantee it will be debated somewhat in that committee.

Now, the President also, in my humble opinion, when he fully understands this matter, cannot possibly insist on retaining the responsibility to determine how much of each industry is going to be given to each of these foreign nations. In the first place, it would be suicide for him to continue to do it. In the second place, it has no semblance of principle, because if he determines today—which means his advisers—that a certain tariff will not interfere with a certain industry particularly here, or he wants to give it to a certain nation, in 24 hours, through a manipulation of currency of that foreign nation or those foreign nations, through permits, trade permits, exchange permits, and the many other subterfuges that they use, they would immediately make ineffective or inoperative anything that we do.

I am under the distinct impression the President will understand by the middle of next session just what is happening to this country, because this very act has done two things to this Nation: it has made us dependent on foreign shores, across major oceans, for many of the strategic and critical materials. We are getting 900,000 tons of manganese annually from India. That is approximately one-half of our annual consumption of manganese. We cannot make a pound of steel without it, and we won't be able to get a pound of it from India hours after the war starts, the third war.

Now, one of our military strategists testified, in language a little more spectacular than I use in some of my expressions, that you don't make your steel in Pittsburgh, you make it in India, and when the war starts you can't make any more except what you have in stock and whatever you are producing currently within the area you can defend. That is what you are limited to. He said you don't produce jet engines in Cincinnati, you produce them in Nigeria, where you get the columbium, without which it is very difficult to make a jet engine. He said you don't produce these materials here at all. Anything that takes tin you produce in the Malayan States and Indonesia, when you have all the tin you need right in this hemisphere. The State Department wants to abolish the only smelter in the Western Hemisphere, tin smelter. I asked this witness if I had heard him right, and he assured me that I had, and I said, "You'd better go back and get a new set of orders. Congress will never do that," and I don't think they will. So you have a matter of national security; you are now de-

pendent on many of these minerals, and they are not all minerals, there are also agricultural materials in foreign nations where you cannot possibly get them when the war starts.

As a result of this division of the markets, deliberate division of the markets, under the 1934 Trade Agreements Act, you have made your civilian economy over into a war economy; instead of producing the lead and zinc in the United States that you can produce, increasing very materially your production of that important product within the confines of the United States, we have reduced the production of these materials, and these workers gradually over the years have moved into manufacture and processing of largely war equipment. We have become the producers of war equipment in a war economy. It scares some of us to death, because if war starts tomorrow and you ship this stuff into Europe and it is stored there, most of it obsolete when it is manufactured, and all of it will belong to Russia in a week, just like it happened in Indochina. But you are afraid to stop manufacturing it for fear of unemployment. So those men are employed in manufacturing this obsolete equipment and giving it to your potential enemy, which you are doing anyway, building up the industries in Europe, and they are trading in all the foreign nations that are potential enemies of the United States. Mr. Attlee, who just landed here yesterday, they said was over in Russia arranging to sell the stuff to them that we were appropriating the money for in Congress; and then he went to Peking, and did the same thing.

Now, you are doing it under the 1934 Trade Agreements Act. Do you like it?

Mr. YOUNG. No.

Senator MALONE. You don't like it?

Mr. YOUNG. No.

Senator MALONE. Well, I would like very much to see that in the resolutions of the American Mining Congress, which has responsibility of talking for the mineral industry of the United States. I would just like to read that in words of one syllable in their resolutions when I get back to Washington.

Why don't you say, sit still and don't extend it?

Mr. YOUNG. We probably haven't given full consideration to that phase, and I will get the committee together and consider that.

Senator MALONE. Will you advocate it?

Mr. YOUNG. I will advocate it, in view of what you have said here on that subject. I didn't realize that that was the thing that would be of the most benefit to those of you who are doing such a wonderful job for the preservation of our American economy, and I will get our committee together and talk that over.

NECESSARY RESEARCH IN MINERAL PROCESSING

I would like to say one thing, if I may, because of the wonderful things in these reports of your committee. You know, on this natural resource problem—and Mr. Holderer here, who is on your staff, knows, because we have worked together in the defense-materials program—there is one thing that I do hope that the Congress will give consideration to, which is under the Department of the Interior, and that is carrying to completion the investigation of certain raw materials of which this country has large tonnages but which we cannot now

beneficiate to produce an acceptable commercial product. There are three of them. First of them is manganese. I think that—while we are not at war we should find out the best process that we can develop to bring our low-grade manganese deposits up to commercial standards; and, second, I don't know how far along this is, but it is the recovery of alumina from our high aluminum deposits in the United States. There are several of them. This process must be developed. And the third, which has had a lot of money spent on it is the conversion of solid fuels into liquid fuels, and I think those three things should be prosecuted to completion.

Senator MALONE. They should have the money that is required to find out how to do the job. Now, that is in the Western Hemisphere. Now, of course, we are bringing in a lot of manganese from South America, a project that we got going during the defense program in 1952, but that will not be in for a couple of years yet, I believe, George.

Mr. HOLDERER. About 1956.

Mr. YOUNG. But you are doing a wonderful job for the defense of this country, and the mineral industry wants to cooperate with you in every way they can; and I value your judgment and the suggestion you made here, and I will take it before our committee for consideration.

Senator MALONE. I would appreciate that very much, because it is not that I would want to influence your opinion, but I would like for you to make your opinion straightforward, so that when we get it on the Senate floor, in the Senate Finance Committee, and before the House Ways and Means Committee we can say what we mean, in words of one syllable so that everybody immediately understands it. Now, I would like at this time to insert the findings, also, on page 5 of the report, in the beginning, following the recommendations on page 3, that were inserted earlier. There are 14 of them, and they are very clear. I do this because anyone having a copy of the hearings here will know the status of the committee's work.

FINDINGS

The findings include conclusions developed from the 10 parts of published testimony and are the foundation for the 14 recommendations for the United States Senate. This is in conformance with Senate Resolution 143 directing the committee to determine the accessibility of the critical materials to this Nation in wartime, and for our expanding economy and security.

1. The Western Hemisphere can be defended and will be the only dependable source to the United States of critical raw materials in the event of an all-out war.

The delivery of any such critical materials to the Nation across a major ocean during such a conflict will be highly problematical.

The evidence indicates that it now is possible for the enemy to destroy the production of critical materials at their source and, in any case, sealanes will be even more difficult and costly to depend upon than was the case during prior wars.

The Western Hemisphere can be made self-sufficient in the production of critical materials which are essential in war.

Since the testimony of competent witnesses indicates that the Western Hemisphere will be the only dependable source of critical raw materials in the event of an all-out world war, it is imperative to the security of this Nation and to the nations of the Western Hemisphere that we and they foster the greatest measure of self-sufficiency in the production of such materials and continually study all possible devices that will encourage the expansion of hemispheric production in this vital field.

It is vital to our domestic welfare economy and security that maximum economic production be maintained, first, within our own borders and, second, in the Western Hemisphere.

2. During the last more than a quarter of a century established procurement practise have dangerously increased our dependence for the critical materials upon nations across major oceans without which this Nation cannot survive.

We must avoid dependence upon overseas supplies to the extent that these supplies could suddenly render us impotent by withdrawing supplies of critical materials during a world conflict, or could use such dependence as a political or economic bargaining lever.

Testimony is abundant that our domestic and foreign policies have been based on the false assumption that the United States is a have-not nation insofar as the supply of critical raw materials necessary to this Nation in wartime is concerned.

This testimony also shows that in many instances the United States has expended enormous sums of money to underwrite foreign fiscal systems and world policies of nations whose friendship is deemed of great importance because of their control and possession of raw materials.

This misconception that we are a have-not nation has found wide acceptance by the public through confusion between the statistical and engineering terms, "proved commercial reserves" and "potential and latent resources," which include developed ore, probable ore, possible or inferred ore to designate supplies of ore in various states of development.

This confusion has led to predictions over the past two decades that we would soon exhaust our supplies of petroleum, iron ore, copper, lead, zinc, tungsten, mercury, and other critical materials. Expert testimony before this subcommittee made it crystal clear that there were more known commercial reserves of critical materials in the United States than ever before in the history of this Nation.

In the meantime we have consumed more than the total quantity of proven commercial reserves of two decades ago.

The potential latent resources or reserves are more than ever susceptible to discovery today by modern techniques and exploration methods, requiring only a financial incentive to be found.

Evidence was presented which showed that this country was led into the mistaken conclusion that, according to the known reserves of critical materials, including petroleum, tungsten, manganese, zinc, lead, and other minerals, "we would exhaust our supplies and they would be virtually depleted" within 2 to 12 years.

Documents were introduced into evidence which stated that in 1944 the Government was advised to conserve its minerals and that it should purchase some critical materials from foreign countries, including Russia. It was testified that this advice played a part in the subsequent increase in United States dependence on foreign nations for critical materials which are available in this Nation and in the other areas of the Western Hemisphere.

3. Less than 1 percent of the areas of this Nation has been included in geological investigation; only 12.7 percent has been geologically mapped, and 31.1 percent topographically mapped by the United States Geological Survey; and that the Survey started its mapping work in 1880.

4. The evidence indicates that Federal tax laws definitely retard the production of critical materials in this Nation.

The principle of depletion allowance has materially increased the known reserves of petroleum and natural gas and if extended to other critical materials would increase the incentive to discover and develop additional supplies.

5. The United States cannot possibly exhaust its present and potential fuels supply including petroleum and coal in the foreseeable future. The absolute necessity for going-concern industries cannot be overemphasized. This is particularly essential where materials cannot be stockpiled, as coal and petroleum. Testimony is conclusive that the petroleum industry is a thriving going-concern business growing through the effect of a continually increased market and the tax policies including depletion allowances, but emergency dependence must be on the going-concern indusrty.

Enormous oil reserves are found in the shales and/or coal of Colorado, Wyoming, Utah, Kentucky, Indiana, and Ohio, as well as in Canada. It has been estimated these shales contain over 200 billion barrels of oil. Experimental work by the Union Oil Co. and Bureau of Mines in pilot plant operation shows that petroleum production from this source is entirely practicable and that vast amounts of oil may be produced in the foreseeable future. The Green River formation in Colorado alone has been described as an area of 1,000 square miles with an underlay of oil shale 500 feet thick averaging a recovery of 15 gallons of oil per ton.

Coal reserves are unlimited for energy demands as well as for petroleum production. The coal industry is in a state of decline and steps should be taken and studies should be made with a view to expanding the uses of coal.

6. An International Materials Conference was established in December 1950 by the State Department without the express consent of Congress. It was testified before the subcommittee that the IMC was set up in lieu of the International Trade Organization which Congress had refused to ratify at an earlier date.

There is evidence before the subcommittee that the operations of the IMC and international control of production and consumption allocations may have depleted and retarded fulfillment of stockpile objectives.

The IMC has now been discontinued. A new effort to establish a similar international organization is currently in progress in the United Nations Economic and Social Council, based on a resolution passed by that body on April 30, 1954.

An international organization, setting up controls over the distribution of the production and consumption of the world's goods could inhibit our own going-concern industries.

7. Ore is a mineral aggregate that can be extracted at a profit. Through properly regulated foreign trade the incentive for risk capital necessary to develop additional reserves and establish a going-concern critical-material industry will be available.

8. Mines once closed down require years of time and tremendous investments to reopen. With experienced workers and technical staffs widely scattered, machinery liquidated, mines flooded and caved, much of our once available reserves are destroyed, and prospecting for new reserves is discouraged. Failure to realize the situation could mean tragedy to our economy and our material security.

9. Numerous administrative agencies and departments of the Government are involved in the stockpile program, or in efforts to increase the production of critical materials. They act independently of each other and none are charged with the complete operation. Many are not cognizant of the end objectives of the program. Their activities are marked by confusion and delay, frequently defeating the intent of Congress.

10. The Securities and Exchange Commission's "purpose is to provide full and fair disclosure of the character of securities sold" and "to prevent fraud." Complaints were made that the discovery and development of new minerals was retarded by actions of the Securities and Exchange Commission in that it improperly attempted to determine the feasibility of an enterprise and in that public announcements of investigations of securities sales were made prior to confidential inquiries justifying such announcements.

The Chairman of the Securities and Exchange Commission assured the committee that "the Commission does not pass upon the merits of any security or feasibility of an enterprise offering securities for public sale." The Commissioner also stated that there would be no publicity given to any administrative investigations before the Commission authorized a public hearing or announces a public investigation.

11. Titanium production is a must. It is a wonder metal without which this Nation cannot produce the most effective bomber plane flying at supersonic speeds with a range of five to seven thousand miles. Titanium will increase both the range and speed of these planes.

(*a*) This Nation needs a minimum production of 150,000 tons of titanium annually. The manufacture of the proper type of military planes without this wonder metal is impossible. We are producing approximately 2,000 tons annually.

(*b*) Three agencies share the responsibility for the production of this indispensable lighter, heat-resistant metal, which is far stronger than aluminum, and less than half the weight of steel. The Secretary of Defense, the Office of Defense Mobilization (ODM), and the General Services Administration (GSA) work on the program. The ODM represents the consolidation of about 15 such agencies.

(*c*) In 1953 the Secretary of Defense recommended the production of 35,000 tons of titanium annually by 1956. The ODM reduced the figure to 25,000 tons and up to September 21 of that year the GSA had let contracts for 13,200 tons and the actual annual production was little over 2,000 annual tons.

As of May 15, 1954, the Secretary of National Defense still recommends the production of only 35,000 tons, the ODM will permit contracts up to 37,500 tons. The GSA is now in process of negotiating additional contracts for an additional 16,500 tons per annum.

There is no provision for checking the contractees and for facilitating the work. Australia now furnishes the rutile for the Henderson, Nev., plant where two-thirds of the production is located—and India furnishes most of the ilmenite for the New Jersey plant, which is the source of the remaining one-third. Neither source would be available in time of war. There is more ilmenite in the United States and southern Canada than we can use in a century.

The industrial use of titanium, in addition to the military needs, could amount to from 5 to 10 billion dollars annually in the near future—it is the strongest light metal known and in addition is noncorrosive, even in sea water. Many industries, including the chemical field, have announced that they can use the metal as fast as they can be assured a continuous supply.

12. The commercial use of nuclear power could be the greatest potential source of improvement, starting in the desert and mountainous areas where other fuels and hydroelectric potentials are high cost or nonexistent.

13. A stockpile of each critical material must be maintained which, coupled with going-concern production within the Western Hemisphere, will be ample to meet the military and civilian needs. Such a stockpile can be decreased as the going-concern production is increased.

The best wartime insurance of the adequacy of our supplies of critical and strategic materials is a healthy, expanding mining industry combined with well balanced, ample stockpiles.

The availability of tin is a matter of deep concern to this Nation. The far eastern resources may well prove unavailable to the United States in any future war. The Western Hemisphere resources contained in Bolivia are more than adequate to meet the United States requirements. At present the United States Government is operating the only tin smelter in the Western Hemisphere. Recently efforts have been made to dismantle this smelter. Testimony received by the committee proves that this would be foolhardy and shortsighted. It is essential that we have a going-concern tin smelter in the United States capable of supplying the United States in the future and to supplement our stockpile requirements.

14. Laboratory research, pilot plant experimentation and exploration is important in the interest of national defense and must be implemented—for new and improved methods of beneficiating critical materials and for new uses, substitutes and replacements—and to facilitate the discovery of new reserves.

The difference in country rock and reserve ores often lies in an improved beneficiation process.

Numerous new uses for metals and materials have continually been developed over the years through laboratory work and pilot plants, among them titanium, zirconium, columbium, thorium, and uranium and new materials such as synthetic mica.

Many of these can be utilized as substitutes and replacements for scarce materials. They have opened up entirely new and unexplored fields of increased speed and power. There is every reason to conclude that if properly encouraged, much greater and broader progress in these fields lies immediately ahead.

Senator MALONE. Now, I am very interested——

Mr. YOUNG (interposing). Mr. Powell, who has followed this legislation business, says as to these trade agreements, if the trade agreements legislation expires it doesn't alter the agreements that have already been made.

Senator MALONE. I already explained that. It doesn't affect the trade agreements that have been made at all, but the President, by a simple letter demand upon the nation with which such trade agreements have been made, can cancel them out. You understand that, Mr. Powell?

Mr. POWELL. I was just trying to explain to Mr. Young that one of the reasons that our committee took the action that it did was because some of the committee members had in mind that the present agreements would keep right on going.

Senator MALONE. What is your name?

Mr. POWELL. William I. Powell.

Senator MALONE. Who are you connected with?

Mr. POWELL. With the American Mining Congress in Washington.

Senator MALONE. Is that your sole job?

Mr. POWELL. Yes, sir.

Senator MALONE. Well now, they didn't want to cancel these trade agreements; is that it?

Mr. POWELL. No, no; they felt that the agreements that are now in existence keep right on going in any case.

Senator MALONE. They don't. The President can handle them in 10 minutes. It would take him about that long to dictate a letter, serving notice of cancellation on the country with which such agreement is made. You understand that?

Mr. POWELL. Yes, sir, I am glad to get that.

Senator MALONE. Why don't you just take Mr. Young back and get your resolutions committee together and write a resolution? I will give you a copy, one that will do it. It will be very helpful to the country and helpful to this committee.

Mr. YOUNG. We would be very glad to have the copy, Senator. I can assure you that it will receive full consideration, but we thought, as Mr. Powell says, that we were presenting, as I said a while ago, the strongest thing, that would be of the most help and most effective.

FUTURE COMMITTEE WORK

Senator MALONE. Now, Resolution 271, that continued the work of this committee, took in a little wider scope; substitutes, replacements, laboratory work, and having in mind the very things that you have mentioned, and I am very glad that you brought them out. Manganese—We have in the audience here my friend, Mr. Ralston, of the Bureau of Mines, who probably knows as much about the status of the investigations on manganese, the laboratory work, as any human being. We will probably ask him to appear before the committee before we finish the work, and I think he is going to South America with the committee in an advisory capacity, because he is one of the many—not just a few—engineers in the Bureau of Mines who have spent their lives in certain areas, certain minerals.

Mr. YOUNG. That's right.

Senator MALONE. And they know about these minerals; but all of these hand-raised economists in the reports that have been made for two decades get their information and data surreptitiously, never mentioning the Bureau of Mines, and then, like the National Resources Committee, that printed five volumes or more, early in the Roosevelt administration—all of that was a promotion of imports from foreign nations diverted, having a fixed objective already, then slanted the information they secured from the Bureau of Mines to meet it, taking reserves as meaning specifically if there are 3 years' known reserves of some mineral or 20 years' known reserves, they just take it, for example, for granted it is like cans on the shelves; when you use that number of cans you are out. Well, all of the engineers and economists that know anything about the mining business know—and certainly, Howard, you know as well as any human being on earth—that the reserves, when an engineer says that you have a certain number of years, certain number of tons of reserves, that that is the rock that it will pay to mine at the moment.

Mr. YOUNG. That's right.

Senator MALONE. That while you are mining that you may find three times the amount and changing economic conditions brings in lower grades.

Mr. YOUNG. True.

Senator MALONE. Like, for example, we furnish the money to England to build up large stockpiles of zinc and lead. All the information is in the hearings, 11 volumes of published testimony. They build a large stockpile of lead and zinc, costing them nothing. We are giving them the money to buy it anyway. Then suddenly, about a year ago last February, they started shipping it into the United States under this very low protection, low duty, clear below any difference of cost of production, but even if it weren't, they don't need to make a profit, anything they get out of it is profit, so they knock the price of zinc from 16 cents down to 10 cents, lead from whatever it was, 5 or 6 or 7 cents cheaper, and they turn all these reserves, most of them in the United States, into country rock. They are reserves at 16 cents a pound and they are country rock at 10 cents a pound.

Mr. YOUNG. I know that all too well.

Senator MALONE. But the President doesn't, God please him, and he has advisers there that live on that Atlantic coast that have only eyes for Europe; but on the security end of it, even if he is not convinced that the economy of this country should be kept up on a civilian basis and not a war basis, the security of this country will touch him, because you can't get those reserves, those minerals and materials, when the war starts.

Now, I want to say at this point, too, that there are 77 of these materials; about 40 minerals, 37 agricultural products, all named here, and we had the Department of Agriculture testify. This is not a mineral report, this is a critical materials report.

Mr. YOUNG. I know it is.

Senator MALONE. There are certain columnists and newspapers in this country purely on an economic one-world basis, that try to say it is a mineral report. It is a critical materials report.

Mr. YOUNG. I know it.

Senator MALONE. No one doubts that when the laboratory experiments—and, by the way, one of these recommendations—they recommend $50 million being made available annually over a period for laboratory work. If they need 10 times that amount it could be well spent, wherever it can be well spent by the Government, in cooperation with private industry.

Mr. YOUNG. That's right.

Senator MALONE. Everyone knows that there are more aluminum clays in this country than you could use in 10,000 years in the production of aluminum. It is not what we call an economic product yet, but it will be if you continue the laboratory work.

Manganese, more manganese in Brazil than we can use in a hundred years, fully available to us, and in our own country probably the amount could be increased by 2, 3, or 4 times, just on that economic basis, economic approach, having a duty and making up the difference between the wages and the taxes and the other costs of doing business. You think, do you not, Mr. Young, that the workingmen of this Nation and the investors are entitled to that protection?

Mr. YOUNG. Definitely.

Senator MALONE. Then, if you have to go above that for any reason, that is a special consideration by Congress.

Mr. YOUNG. That's right.

Senator MALONE. And they can consider it at any time. It is so simple that it meets every argument.

I deeply appreciate you coming down here this morning, because I have long felt that there was not a complete understanding of this whole picture. All this committee can do is to be an agent of Congress, to return to each Congressman and each Senator the findings of the committee.

Again I will say that no one single individual in the United States of America can fix the policy and the principle upon which foreign trade will be conducted in this country. The President couldn't do it.

Mr. YOUNG. No; I realize that.

Senator MALONE. No Senator can do it; 96 of them can't do it, because they have to have a majority in the House, and the President has to sign it, or they have to have two-thirds of both Houses. What the President says is persuasive. However, I would follow him a lot further in military strategy than I would in economy and in fixing the principles of foreign trade and the economy of this country. He has spent all of his life in the Army, many years outside of the country, and he has to depend on advice that he gets. I happen to know some of the sources and I am not particularly pleased with some of the sources. However, right in your own American Mining Congress you have the producers and the engineers that know the world picture and their influence can be tremendous. Disregard what I say, disregard the committee's report if you don't like it, disregard what anybodys says. You are the men who have the judgment in this thing.

Mr. YOUNG. Well, we are very appreciative of this, of the committees' report. We have no criticism, nothing but praise for the report. It is the first real study that we know anything of that's been made and it's made available to everyone who will take the time to study it, and I think it is one of the most important and constructive contributions that has been made to this country in the lifetime of many of us and our fathers and grandfathers. Now, that is the way we feel about it from the standpoint of what we know about the report today. I will say I haven't personally studied the 10 volumes, but I am going to as I can do it, and we want to cooperate with you and your committee, and we appreciate your frank statement to us on this, and I appreciate your inviting me down here.

Senator MALONE. Howard, I knew there could be no misunderstanding.

Mr. YOUNG. I would like to have a copy of that resolution.

Senator MALONE. How soon do you have to have it; by noon, will that be all right, or by 2 o'clock?

Mr. YOUNG. Yes; by 2 o'clock.

Senator MALONE. Off the record.

(Discussion off the record.)

Senator MALONE. On the record. We have Mr. Dick Lund, of the Battelle Institute. Mr. Lund, will you come forward. Mr. Albert Richardson is with you, I believe.

Mr. LUND. Yes.

Senator MALONE. You can have him right here at the table with you.

Mr. LUND. All right.

(By direction of the chairman the following is made a part of the record:)

AMERICAN MINING CONGRESS—A DECLARATION OF POLICY, ADOPTED AT SAN FRANCISCO, CALIF., SEPTEMBER 20–24, 1954

TARIFFS

We endorse the Government policy which recognizes that an adequate "mobilization base" of metal and mineral production for our national security is essential. To accomplish this our Nation must look to its domestic production and ore reserves for the major portion of its mineral supply, despite progressive increase of imports of some metals and minerals.

Experience has shown that we cannot depend on foreign ore reserves as a source of supply in an emergency, however important it may be to import some metals and minerals to supplement domestic production and to fill our stockpile with materials in which we are deficient. World political conditions, as well as hazards of possible air and submarine warfare, support this conclusion.

We recommend, therefore, that Congress exercise its authority over tariffs to be administered for the welfare of the American people and provide reasonable tariff protection. In this connection we commend the United States Tariff Commission for its careful study and complete report to the Congress as well as its recommendations to the President on the industry's application for increased lead and zinc duties.

We commend the Members of the United States Congress who worked tirelessly to secure the approval of the Tariff Commission's recommendation. It is regrettable that the President did not see fit to accept the Commission's recommendations. His alternative program, while having certain desirable features, is at best a stopgap solution and does not offer any real long-range cure to the problem of the domestic mining industry.

We favor the enactment of an excise tax on imports of lead and zinc, as well as other metals and minerals with similar problems, which may be suspended whenever prices are at an economic level that will permit the domestic mining industry to maintain an adequate "mobilization base" for national security.

Since the executive department of the Government has not seen fit over the past years to adhere to the purposes of the escape-clause and peril-point provisions of the Trade Agreements Act, we favor removing the authority of the executive department to act on the Tariff Commission's recommendations and favor the placing of such responsibility for approving or disapproving the recommendations in the hands of the Congress where the constitutional authority rests. We also favor allowing the Trade Agreements Act of 1934, as extended, to expire on June 12, 1955.

The United Nations has established a Commission for International Commodity Trade. This Commission is empowered to recommend agreements to member countries such as those provided in chapter VI of the Habana charter, which was rejected by the Congress of the United States. We commend the State Department for its vigorous opposition to the formation and constitution of this new United Nations Commission. The powers of this Commission are far greater than those of the now disbanded International Materials Conference, which we strongly opposed. We have not changed our position with respect to international commodity agreements, and, accordingly, we oppose any United States participation in this new United Nations Commission, or in any new international commodity agreements which may be sponsored by the Organization of American States.

National security requires a healthy domestic mining industry with ample productive capacity and experienced working forces. Our greatest protection is industrial strength. We recommend maintenance of the fullest possible capacity for production of strategic and critical metals and minerals within the United States.

Senator MALONE. We are glad to see you.

STATEMENT OF RICHARD J. LUND, MANAGER, INFORMATION AND ANALYSIS DEPARTMENT, BATTELLE MEMORIAL INSTITUTE, COLUMBUS, OHIO

Senator MALONE. Now Mr. Lund, you are of the Battelle Institute?

Mr. LUND. Yes, sir.

Senator MALONE. I want to say at the outset I have a high regard for the Battelle Institute, as a research organization of far-reaching reputation, and anything they would have to say in the matter of the status of research work in the various fields and current problems carries great weight with this committee.

Now, Mr. Lund, if you will identify yourself for the purpose of the committee and introduce your associate and give us any statement that you care to make for the benefit of the record.

Mr. LUND. Senator, my name is Richard J. Lund, employed by Battelle Memorial Institute, Columbus, Ohio, one of the large industrial research organizations in the world. My title there is manager of Information and Analysis Department, having to do largely with raw material studies, industrial market research, diversification, studies of that type. Mr. A. C. Richardson is technical director at Battelle Memorial Institute. I have no written statement, Senator, to submit. I wasn't sure until I got out here and talked with Mr. Holderer just what aspects of this you were primarily interested in.

Senator MALONE. We are particularly interested, Mr. Lund, under Senate Resolution 271, directing the continued work of this committee in expanding the work in substitutes, replacements, status of laboratory work in connection with any part of that field that might lead to making the United States and the Western Hemisphere more self-sufficient—that being the area that has been determined we can defend—in the production of the critical materials particularly, because critical materials—the definition is materials that have been a part, or all of which have been imported into the United States.

Mr. LUND. Yes, sir. I might say that I have had some experience in this field. I have worked closely with Mr. Young in the War Production Board and predecessor agencies for 4 years, in charge of miscellaneous minerals, and I have certainly followed very closely and with much interest the work of your committee in all these areas. I haven't had, as Mr. Young said, a chance to read and study all the volumes, but I am much interested in the summary, at least, of your report, and just as soon as time permits I am going over all of these with as much care as possible. You have done a wonderful job in bringing together this information that is so important.

Senator MALONE. Mr. Lund, what I want to say at this point, and if you will convey the information to your organization, is any suggestion that they can make will be received and considered, because one of my pet theories is that you can't do anything by yourself. It takes a ball team, and they can't all be second basemen. You have to have the field covered.

Mr. LUND. I thoroughly agree with that, Senator.

Senator MALONE. You have to have the bases covered.

Mr. LUND. Yes, sir.

Senator MALONE. You are covering a very important base.

RESEARCH TO IMPROVE STRATEGIC MINERAL POSITION OF UNITED STATES

Mr. LUND. I thought that it might be, and I have worked up a few notes of interest to talk from here, to speak about the role of research in improving the strategic mineral position of the United States. Battelle, of course, is a strong believer that major contributions can be expected from research if an adequate program is planned and pushed properly.

Senator MALONE. Right at that point, it is very interesting, has there ever been any field where we lack some proper alloy or some proper material to do a job, and suddenly it becomes profitable, so that money can be expended in research? For example, titanium. That now is occupying the attention of a good many important firms.

Mr. LUND. Yes; I think there are lots of examples of that, Senator. Titanium, of course, is one.

Senator MALONE. Of course, you always get the answer if the money is available for the research; after it is profitable, then you get the money.

Mr. LUND. Yes; and if raw materials are available. If you are speaking of a relatively new material, I think one good example of that, Senator, is the rare earth picture, where in the past we were virtually completely dependent on India and Brazil for our supplies of monazite, and these were limited supplies that these countries could make available to us.

Senator MALONE. India, by the way, stopped the shipments.

Mr. LUND. A long time ago, about 1947.

Senator MALONE. In peacetime, which is very interesting.

Mr. LUND. 1947 or somewhere along in there they embargoed exports, but with the discovery of these bastnaesite deposits in California, almost in Nevada—I think it is practically on the line—and the discovery of the magnitude of the Idaho deposits, we now find that we have all of the rare earths, at least, that we need in this country, and that these are available in great abundance that could satisfy alloying uses in steel in large tonnages, where we didn't have enough of the material available before to consider such uses. This is just one of these illustrations.

Senator MALONE. But it has suddenly become profitable?

Mr. LUND. Yes.

Senator MALONE. And then there was an incentive for the prospectors and explorers to look for this material, because they could make money when they found it.

Mr. LUND. Right, except now I think the main problem is markets where it can be used in sufficient volume to permit a large-scale mining program.

In view of the fact that it takes time to do this research work, we are firm believers in the general principle of what we might term "stockpiling research, stockpiling technology."

Senator MALONE. Explain that a little more. I am very interested in it.

Mr. LUND. Well, it simply means, Senator, that in some of these problems, tackling the recovery of materials from very low grade domestic sources, let's say, or from other domestic materials, it means that we do the research ahead of time and stockpile the results of that research. You then know that you have processes developed that you

know can be utilized, if and when they are needed in an emergency. Some of these will not, perhaps cannot, be economic and competitive with normal large, richer materials from large world suppliers, but if those supplies are cut off this research shows you how to make use of materials that would be available domestically or within the Western Hemisphere under those conditions.

Senator MALONE. Now, right at that point, incentive is necessary to discover these deposits in the first place and to secure the money necessary for laboratory work. It is also necessary to have an incentive, a price incentive, demand incentive, so that when you whip the problem you can get your money back, unless you get an appropriation from the Government; isn't that necessary?

Mr. LUND. That is right, and some of these things may be so far from an economic or from competitive situations that Government support is necessary. Some research, of course, is going to be done. I simply want to enumerate some of these fields where research can contribute, if I may.

Senator MALONE. I want you to do that, but first, since you brought it up—and I am very glad you did—about a competitive product or an economic product, a competitive product under free trade, where there is no duty or tariff, duty as the Constitution calls it—and we are not really regulating foreign trade as the Constitution sets down—there is no duty or tariff, then the competitive product would be one that would compete with the product from the low wage, low taxes, and low cost of production nation, would it not?

Mr. LUND. Yes, sir.

Senator MALONE. Now, what I call economic production, and I would like to know if you agree with me, or maybe you would have a better term; there has to be some term to describe it. Economic production in this country would be that regulation on a flexible basis, which is now the law of the land if it reverts to the Tariff Commission, if this 1934 Trade Agreements Act were allowed to expire, fixing that duty—according to the Constitution it is called duty—to make up the difference in the wages, effective wages. Do you know what I mean by effective wages?

Mr. LUND. Real wages.

Senator MALONE. Difference in the effectiveness of the wages, efficiency; difference in the effective wages. The Tariff Commission knows exactly how to determine that factor, taxes and other costs of doing business in the chief competitive nation, and in my opinion an article in this country is competitive and economic when, through that protection, it has a market.

Mr. LUND. Well, Senator, I would prefer to confine my remarks——

Senator MALONE (interposing). I wanted to define that for the purpose of the record, because there is no product that I know anything about, from textiles, raising onions or manufacturing tool steel or producing minerals for agricultural products, that can't, with our materials, our machinery and methods, and the low wages and low water transportation, put you out of business without any duty making up that difference in the wages and taxes and costs of doing business. There is just nothing that you can mention that can't run you out of business. Even Mr. Ford has got a $1,300 Ford in New York now he is selling. I don't blame Mr. Ford for having 26 plants outside the

country and using that $2, $3 labor in his assembly line methods. I blame the Congress for making it profitable.

Mr. LUND. Yes.

Senator MALONE. You understand that.

Mr. LUND. This is a complex problem.

Senator MALONE. It isn't complex at all.

Mr. LUND. Well, it all depends on how much we can produce against how big a price gap, and all of that. It becomes a very complex subject, and I would prefer, Senator, for now, if I may, to confine my remarks to this matter of the role of research, and leave this other matter, if I may.

Senator MALONE. All right, but let me make the statement then that a duty or tariff fixed on that basis, flexible basis, making up that difference in wages and taxes, never kept anything out of this country in the world that we needed, but it comes in on your basis of low cost.

Now, will you proceed in your own way.

FIELDS AIDED BY RESEARCH

Mr. LUND. Yes, sir. I might summarize a number of fields in which research can contribute, we feel, in this, the matter of helping to improve the strategic mineral position of the United States. First, let us say, by improving discovery techniques. This is a very important area. A tremendous amount of research has already been done in perfecting geophysical methods and geochemical methods, but there is still a lot to do in finding methods by which we can locate hidden ore deposits better.

Second, by developing better mining and drilling methods and equipment. We can judge the tremendous amount of work that has gone into this field by looking at this exposition of mining equipment right here in San Francisco today. We see some beautiful illustrations of what research has done in this area of mining equipment that makes possible the recovery of lower-grade materials from domestic sources.

Third, by improving beneficiation methods, especially as applied to marginal materials and the recovery of byproduct materials in small quantities. By and large, beneficiation is doing a good job now in our most efficient plants; recoveries are high, but we feel that certainly there are opportunities of applying these methods to marginal materials and to the recovery of byproducts that will contribute to a solution of this problem.

Senator MALONE. Are there any specific instances that you can give us for the benefit of the record which would be helpful, realizing, as few scientists do, that people who read the record or hear your testimoney are not experienced. As my wife often tells me, I leave out a lot of things, and people don't understand what you are talking about.

Mr. LUND. I don't know of any specific problems right now. Well, here is one.

Senator MALONE. Uranium, for one thing.

Mr. LUND. Oh, yes; uranium, of course, but rutile, we'll say. Here is an ore that producers of titanium like to use now for producing the tetrachloride, and eventually the sponge and metal.

Supplies of rutile are quite limited worldwide. We know there are tonnage deposits that are being mined, and that contain rutile in small quantities that might possibly be recovered economically.

Senator MALONE. You are now getting the rutile you are using at Henderson, Nev., from Australia.

Mr. LUND. From Australia; that's right.

Senator MALONE. Which would not be available in the event of a war.

Mr. LUND. That's right. Perhaps a little is coming from Florida, but very little. Then again in smelting and refining and alloying, remelting metals, in general the recoveries are good, losses are not serious, for example, nickel recoveries in alloying are close to 100 percent and chromium recoveries are about 91 percent in making stainless steel.

On the other hand, in some work we did a few years ago we found that in remelting beryllium copper master alloy the losses are rather high—of the order of 25 percent.

Senator MALONE. Before you leave the titanium, ilmenite is a very satisfactory metal to use for the manufacture of titanium, is it not?

Mr. LUND. Yes, sir.

Senator MALONE. And there is more ilmenite, probably, in the United States and Canada than you can use in the foreseeable future.

Mr. LUND. That's right, true.

Senator MALONE. So isn't it about time we adopted some of our methods to that use before a war comes along and stops the shipments from India and Australia?

Mr. LUND. That is right. I think research is being done now, aimed definitely in that direction, and from what I know—from what I don't know—let's put it that way—it might well be that the titanium slag from the Canadian ilmenite operations is now being processed to titanium sponge. I don't know.

Senator MALONE. The Kennecott Copper Corp., or organization, which of course has a very large copper pit in our State, in Utah and elsewhere, have a very large deposit of iron and ilmenite in Canada, in southern Canada, and they are producing and are prepared to produce—and I am not able to quote offhand their production, but they sell the pig iron and they also sell the ilmenite pig, is it called?

Mr. LUND. Ilmenite slag.

Senator MALONE. Ilmenite slag or the titaniferous slag, titanium slag, but it makes it a profitable operation to produce the pig iron if you can sell the slag, and vice versa.

Mr. LUND. That is right.

Senator MALONE. And we have the market, because testimony from Don Douglas of Douglas Aircraft, Bob Gross of Lockheed, and then the experts, know the demands for military planes, that we need 150,000 tons of titanium to satisfy the national defense needs in planes and guided missiles and other material where it could be used on account of its weight-strength ratio and heat-resistant qualities, instead of the 2,000 tons or the 2,200 tons that we are manufacturing annually now, so the demand is there and the money is there for it when your research puts it in their way.

Mr. LUND. That's right. The demand probably would be contingent on lower cost.

Senator MALONE. No, it is not. We determined that definitely. I was very much interested in it. They need the 150,000 tons at the

present price or at any price. They have to have it for a long range sonic speed plane, light enough to carry the fuel to go five to seven thousand miles and drop bombs and come out without refueling; can't do it without this light metal.

Mr. LUND. I see.

Senator MALONE. Therefore, the cost is not a factor. You have to have it, whatever it costs, if the other fellow has it, and we have every reason to believe they have, because they have written 240 technical articles on it, and someone said the other day they were offering it for sale.

Now, in addition to that testimony, I believe the digest of it is in this report, that the commercial planes are demanding it, that they cannot secure it on account of its allocation for national defense purposes, and they can pay as high as $70 a pound for it. It costs $15 to $20, I think $15 for the raw material, I mean the raw titanium. They could pay $70 a pound for it and make it up during the life of the material in the additional payload. Then the chemical industry came in. I never thought about the chemical industry. It is noncorrosive and very few chemicals can attack it, so they want it. There is a tremendous demand in the offing as soon as it is available, at the present price, but no one I know thinks it is going to be $15 a pound very long with all this demand. It probably will go around $4 or $5 or even $2 a pound and then probably it will displace stainless steel, maybe not displace it, displace it for certain things, but the history of all of these metals is you use more of all of them once you get started.

Mr. LUND. That's right. There is a tremendous potential, there is no question about it, in this field of titanium.

Senator MALONE. We say in the report probably a five- to ten-billion-dollar industry.

Mr. LUND. That may be right.

Then, going on to a fifth field, more efficient use of scrap; to some extent this may be dictated by economies but there also may be technological problems involved in this matter. I think for one thing, titanium itself comprised a problem in the usage of scrap. I think they are making progress now.

Senator MALONE. That, they say, will materially reduce the price.

Mr. LUND. That's right.

Senator MALONE. When they can use the scrap like they do the steel scrap.

Mr. LUND. That's right.

Another very important field is the development of economies in the usage of these various materials. Tin is an outstanding example there. In 1940, for example, we produced 19 billion No. 2 tin cans, or equivalent, from 40,277 long tons of primary tin. In 1953 we made 35.5 billion such cans, or equivalent, from 32,706 long tons of tin. This represents a reduction of 57 percent in the amount needed per billion cans. This was made possible by the electrolytic plating of tin, and the lower tin content of solders.

Senator MALONE. Then, right along that line, we are using, the testimony shows, about 60,000 tons of tin annually in this country; if suddenly war was declared economy in the use of tin through the use of substitutes, and only for war purposes, where it is necessary, or for purposes where it couldn't be substituted, where nothing could

be substituted, it could be cut to 40,000 tons, and that amount can be produced in the Western Hemisphere; and that is about the maximum capacity of the tin smelter now operating in Texas which the State Department wanted to shut down, by the way, the only one in the Western Hemisphere.

Mr. LUND. That's right.

Senator MALONE. So this is intensely interesting, exactly what we need.

Mr. LUND. Yes.

Senator MALONE. Then, of course, this field of determining satisfactory substitutes, the one you mentioned right at the start. Perhaps you could use a substitute from more plentiful material; maybe a substitute is still one of the critical materials, but if it substitutes for one of the other critical materials in shorter supply it is still a good move; if they are interchangeable, it would often help.

Mr. LUND. Yes, or by the synthesis of the actual material, such as quartz crystal, for instance, or by the synthesis of some suitable substitute material relief could be had, progress could be made in the solution of this problem.

Senator MALONE. One of the things that these people I identify as hand-raised economists forget is that a situation as of today in a certain metal or material, if laboratory work and investigation is encouraged, tomorrow may be entirely erroneous, an entirely erroneous conclusion.

Mr. LUND. That is right. I might say here that in this whole field of research and development of a lot of information on methods, substitutes, and conservation, I know you are familiar with this, but I just want to put it into the record, that the amount of work done by the War Metallurgy Committee of the National Academy of Sciences during World War II, and more recently by the Materials Advisory Board—until a short time ago it was called the Minerals and Metals Advisory Board—of the National Academy of Sciences has continued this work during the more recent emergency, and there is a tremendous amount of information in all of the reports that have been made through that group, or those groups, I should say.

Senator MALONE. I should like to say this right at the outset, Mr. Lund, that your testimony will be submitted to you for additions or corrections, whatever is necessary, and you can feel free to add anything necessary to round it out and make it understandable to the public.

Mr. LUND. Well, fine. I am very glad to know that, Senator.

Senator MALONE. This is not a committee trying to trap anybody. What we want is information.

Mr. LUND. I know that, I appreciate that. Now, for just a few other examples; I have already mentioned a few examples of such recent contributions. Certainly the outstanding example of developments that have been made through a tremendous amount of research that improve our strategic mineral position, is the taconite development to make use of these low-grade taconites.

Senator MALONE. Tell us about that.

Mr. LUND. Taconite, of course, is the original ore formation. It runs on an average of 30 percent of iron on the iron-ore ranges of the Lake Superior district, from which nature itself, over millions

and millions of years, oxidized the iron and dissolved the silica and raised the iron content from something of the order of 25 to 30 percent up to 50 to 55 percent, in that general average, Rich, is that right?

Mr. RICHARDSON. Yes.

Mr. LUND. This work, of course, has been spearheaded by Mr. E. W. Davis, I think, over a long period of years.

Mr. RICHARDSON. Yes.

Mr. LUND. Mr. Davis of the Bureau of Mines.

Mr. RICHARDSON. I would like to make a correction. You mean E. W. Davis of the Minnesota State Mines Experiment Station.

Mr. LUND. That's right.

Senator MALONE. They have had the cooperation of the Federal Bureau.

Mr. LUND. That is right. And the iron companies themselves have done a lot of research in the last 10 years or so. Battelle itself took part in this research.

Mr. RICHARDSON. Off and on for 20 years.

Mr. LUND. By and large the method, of course, involves simply mining the rock first in open pits—this will be available from open pits—and grinding it up to very fine size. The initial effort, of course, has been aimed at the recovery of the magnetite material. Some of these areas over in the eastern area of the range are much higher in fine magnetite in the taconite and it involves a relatively simple beneficiation method of fine grinding and magnetic separation to recover this. The next step, however, was one that was serious. This produces a very fine concentrate that would blow out of the blast furnace, of course, and this had to be pelletized or sintered to reconstitute it into chunks that could be used economically, transported without loss and used in the blast furnace without blowing it all out the stack.

This has been quite a problem to solve economically, again, at low enough cost to make it competitive, but this has been done now, I think pretty well completed; and plants, of course, are under construction now. You know these figures better than I, Rich. I think plants under construction or definitely planned will be capable of producing something in the order of 10 million tons.

Mr. RICHARDSON. Ten million tons.

Mr. LUND. Of concentrates annually.

Mr. RICHARDSON. They are upping the figures all the time.

Mr. LUND. So this is certainly an outstanding example of coping with the problem of depleting our high-grade commercial shipping ores, direct shipping ores, and World War II was a big factor in that, of course.

We now have assurance of plenty of raw material and a process to utilize these lower grade materials for many, many years, billions and billions of tons of taconite up there on the ranges being available.

Senator MALONE. For the foreseeable future, you will have plenty of it; right?

Mr. LUND. Right.

Senator MALONE. Now, of course, taking Canada and Mexico and the Western Hemisphere, there seems to be no doubt of a plentiful supply of iron ore in any foreseeable future.

Mr. LUND. That is right, Senator.

Another example was recently announced by International Nickel Co., development of a process whereby they can recover iron ore from the nickel sulfides, nickel-iron sulfides in their deposits, and by marketing this iron, they are able to utilize lower grade nickel deposits up in the Sudbury Basin; so this is just another example of what research has done in the past. The recovery of cobalt from complex ores by means of the Chemico process up in Idaho, and applying a similar type of process to some of the complex Canadian nickel-copper deposits comprise other examples. Cobalt is virtually indispensable for certain uses at this time, a highly critical and strategic material. Another example is the development of synthetic mullite—it hasn't been publicized much—from domestic material to replace imported kyanite in making superduty refractories for furnaces in the glass and nonferrous foundry industries.

The use of small quartz crystal and blue needle quartz comprised an experience in World War II. It worked us out of a very serious quartz crystal problem. Whereas they used to use processes and techniques ultilizing large pieces only, they developed methods by which they could use this so-called candle quartz, little chunks, and saw it off directly; furthermore, they found they could use quartz that wasn't quite pure, that contained so-called blue needles. That was another research development that worked us out of a serious quartz crystal problem in making oscillators for radios during the war.

Also in the field of substitution, aluminum is replacing large tonnages of copper in electrical uses.

Senator MALONE. Isn't the story of aluminum, for example, about the same as they are starting out with on this titanium? Some of us can remember when it cost $50 a pound.

Mr. LUND. Yes, sir. That is right, and magnesium is perhaps a parallel illustration. That is still in an early stage so far as large development is concerned.

Senator MALONE. But suddenly, when you needed magnesium, you put in the largest plant in the world at Henderson, Nev., and made it. Of course, it was a little more expensive than you could make it from some other process and it was not economically carried on after the war, but there was no scarcity of magnesium; just as soon as we needed it bad enough to spend the money, we got it.

Mr. LUND. That is right.

Senator MALONE. And aluminum, too.

Mr. LUND. That is right. Fortunately, in magnesium we have a superabundance of raw materials. There is no problem there. It is only a matter of power and plant capacity.

Senator MALONE. Well, in aluminum you have not covered the aluminum clays yet. I hope you will. I do not know very much about the details. I know we have provided, through our committee, pilot plants and are ready—at least I am one member that is ready—to provide any needed money or material to further the work. We were led to believe that there is plenty of alumina, aluminum clays, and other materials from which this alumina can be extracted at a price, and it is merely a question of this economic production, but aside from that there is no question in the Western Hemisphere of alumina.

Mr. LUND. Bauxite supplies are really adequate if you consider the whole Western Hemisphere—very close spots in the Western Hemisphere, in the Caribbean; there are certainly adequate supplies of high-grade bauxite.

Senator MALONE. Certainly the research that was done in World War II and following that has indicated that definite methods can be utilized to recover bauxite from these lower grade, higher siliceous domestic materials, this red-mud process. There has been laboratory work within the last very recent period that has almost doubled the reserves of bauxite through methods of extracting the material, the alumina out of this more highly siliceous material.

Mr. LUND. That is right.

Senator MALONE. In other words, 5 years ago we were quoting a certain amount of material available at almost the same price. Now, nearly twice that amount is available.

Mr. LUND. Yes.

Senator MALONE. So it is another example of the men reading the reserve figures and then going off and preaching a scarcity problem and not keeping up with the laboratory work.

Mr. LUND. Yes, sir. That is right.

A few other examples: Glass fiber came in as a substitute for some of the strategic grades of asbestos, a very important material. Electroplated tinplate we have already mentioned. When there was an indicated sulfur shortage back in 1950 or 1951 there was a lot more work done on the possibility of recovering sulfur from sour gas, from sour crudes, and from pyrites that hadn't been utilized before, and that has helped the sulfur problem.

Senator MALONE. Isn't that another example or more proof that whenever a product is needed bad enough, that the money is there to do the necessary work, that over a very reasonable period the scientists and the laboratory work bring it to the surface?

Mr. LUND. Yes, sir; that is right. It is, of course, important to try and anticipate these problems in advance and have the answers available.

Senator MALONE. Your point there is very important, to get the money for this work before it is profitable, which is harder to get.

Mr. LUND. That is right.

Senator MALONE. Whenever there is a profit in it, it is not hard to get; is it?

Mr. LUND. That is right.

Just as a final item that should be mentioned, of course, is all the work that was done in developing the national emergency steels—the national emergency steels during World War II as substitutes for some of the higher alloy steels—that is, steels that contained either more of the given alloy or a different alloy that was more freely available. A tremendous amount of information is available. They know what can be substituted pretty well for something else and still provide the necessary properties. So these are just a few examples of research contributions to strategic mineral problems from a multitude that could be cited.

Then, to narrow this down to a few important potentials in the matter of research now underway, we feel, certainly, that one of the most important is the recovery of nickel, chromium, and cobalt from

the laterites that are available in large tonnages in the Caribbean area generally, Cuba in particular.

Another one concerns columbium. The Bureau of Mines and Geological Survey are doing some work on the recovery of columbium, one of our most highly strategic materials, from the Magnet Cove rutile deposit of Arkansas, and from the red mud derived from the conversion of bauxite to alumina. Colombium occurs in very small quantities in many of the bauxites, and it now goes out in the wasted red-mud residue from these alumina plants, and there would appear to be a reasonable possibility of recovering colombium from these materials.

Of course, the No. 1 problem, that Mr. Young mentioned—and we certainly agree on the importance of this—is the recovery of manganese, the development of processes to recover manganese. Various processes have been developed to recover manganese from low-grade domestic deposits, as well as from open-hearth slags. There is a lot of manganese that is going out on the slag dumps, as you well know.

Senator MALONE. It is used as a cleanser and put out on the dump.

Mr. LUND. That is right. Much of it simply goes through and acts as a cleanser, desulfurizer, in the steelmaking process, and goes out on the slag dump. Small percentages are used to add quality to most of the tonnage steels, however.

Manganese is also a substitute for nickel in stainless steel. We know these manganese stainless steels, so-called, have been developed and used for a long time in Europe. Quite a tonnage, I think, was produced in or following the Korean emergency, but there are still problems of how best to handle it, fabricate it, and so on, that remain to be solved.

Senator MALONE. Can you see ahead on this manganese problem the possibility of a material increase in the production of manganese in this Nation, providing that protection was furnished, as already described, of making up the difference in the wages and the taxes and cost of doing busines, effective wages, of the laboratory work, making available under those conditions a great amount of manganese of this Nation?

Mr. LUND. Well, I don't know, Senator, just what the gap is between the cost of producing a usable grade from low-grade domestic deposits or slags, or whatever it may be, and the present price, let's say, of manganese from large world sources, whether they are Indian or African or what sources.

Senator MALONE. Well, we are talking about the difference between $12, $15 a day, or more wages, and 50 cents a day in many cases, and no taxes, and tremendous taxes in this country that is even supporting foreign nations, so there is quite a lot of leeway.

Mr. LUND. Yes; that is true.

Senator MALONE. And I have always held, I have always thought that the workingmen and investors in this Nation are entitled to that protection; then, if it needs more protection or more special attention to produce them on a security basis, then that would be a special problem for Congress which can readily undertake the investigation without a doubt.

Mr. LUND. This is one field I think, though, where real consideration should be given that if the spread is a long way, that here is a place where you might stockpile your research, you might develop

these methods to utilize the lower-grade materials and assume that the stockpile of manganese ore will tide you over for a period of time until necessary plants are put up to recover it from low-grade domestic material.

Senator MALONE. Well, there is no question but what we have enough in the Western Hemisphere for any emergency.

Mr. LUND. That is right.

Senator MALONE. And the testimony of Generals Wedemeyer, Spaatz, and others is conclusive, I should say, that we can protect and make available in wartime these materials in the Western Hemispheric area, so what you are really working on is to improve the economic position of this country, as well as helping in security. I will ask you this question: It is the general feeling of the chairman, at least, as one member of the subcommittee, that there is no question about the availability of all the manganese we will need in the foreseeable future in the Western Hemisphere. Do you have any doubt that it is available?

Mr. LUND. It is there, if it can be developed and made available, that is sure.

Senator MALONE. Well, it will be developed if it is needed, and it is, and if we do not set down and live by policies set, drawn by Congress or some other administrative officers that make it impossible. If it is profitable, you will find it?

Mr. LUND. Yes; that is right, and if satisfactory arrangement can be made. If we are talking now about foreign manganese, let's say Brazilian, either the Urucum or Amapá deposits way up in the interior; if satisfactory arrangements can be made with the foreign government, if their policies are such as to encourage and not such as to discourage the foreign capital going in there and developing those, yes; I thoroughly agree.

Senator MALONE. Well, then let's put it that way.

We have reached a point now, we have reached it in the last two decades, where we are always making agreements with somebody where they have to agree when our security is threatened. I will touch on that this afternoon at 2 or 3 o'clock.

Mr. LUND. Yes; I want to hear your talk.

Senator MALONE. Under the Monroe Doctrine we laid down a 130 years ago, there was no one agreeing to anything, when our security is threatened it is our business and it is our decision.

Mr. LUND. Yes.

Senator MALONE. Therefore, we do whatever is necessary to be done to protect our own security and the welfare of the people of the United States of America.

Now, if we could just revert to a little commonsense, it might be that these materials will be available to us, not only for the security of the nations that might be able to furnish them in South America—and we are the only security they have from outside attack—but secure them for these nations on a profitable basis to them. We have a tendency to say, well, the people of the United States are entitled to get this cheaper price, if you can find 50 cents a day labor, $2 a day labor. It is almost that plain when you say that we can't meet the competition. Then we appropriate $10 billion a year to spread into these countries to help them do something that they generally do not do,

as we are finding out now, so if we put it into the price we paid, it wouldn't hurt anything; would it?

Mr. LUND. That is right.

Senator MALONE. If we expect Brazil to have decent wages, then we wouldn't expect to get manganese from them at one-tenth the price we produce it here; would we?

Mr. LUND. No.

Senator MALONE. And if we are going to stockpile it from there, or the Government for any reason is going to purchase it, wouldn't it be a good idea just to purchase it from there and pay a price under which they could live decently?

Mr. LUND. Yes. Of course a lot of it depends, too, Senator, as you recognize, I am sure, on the difference in the grade of the material itself. It isn't only a matter of the labor to produce it, but it may well be that your manganese down there is 50 or 55 percent, as compared with some of these very low-grade materials here. Actually, to concentrate these materials and put them into usable shape involves a lot more labor, regardless of the difference in wages paid, than it does to simply scoop it up with a shovel where nature already has concentrated it to a very fine usable grade. This is a very important element that must be taken into account.

Senator MALONE. You are exactly right. That is the reason I use that economic difference, because in my humble opinion the workers in this Nation and investors are entitled to the protection under a duty, a flexible duty set by the Tariff Commission, that knows exactly how to fix it and knows the duty that would make up the effective difference in the wages and the taxes and other costs of doing business. If we must have greater protection for some reason, then a special consideration can be given, then there would be a special consideration of Congress. Now, we did take up sugar beets.

I was not a Member of the Senate, but I was entirely familiar with the work, many years ago. It was a special situation, so Congress worked out a formula so that our associate out in the Pacific could live and Cuba could live and we could live, but it was a special thing. I am talking now about a special consideration, if manganese suddenly turned up to be one of those special considerations, that we had to take care of some special country in the Western Hemisphere, or through competition it had to be handled specially, that the tariff, based on fair and reasonable competition, wouldn't take care of, then Congress is there every year.

Mr. LUND. That is right.

Senator MALONE. There is nothing complicated about it, except we have turned it over to the State Department that doesn't understand it at all, doesn't even know where some of our States are, and certainly wants to give away the industry for some fancied political advantage, international, which it develops now we do not secure. I would not under any consideration say I told them so, but if anyone cares to look over the debates the junior Senator from Nevada had on the Senate floor, starting in 1947, 1948, I would be very happy to furnish the address.

Mr. LUND. Well, that is a complex, very complex problem.

Senator MALONE. I don't think it is complex. I think a little commonsense is needed in arriving at a principle as to what you want to

do. What makes it complex is everybody sharpshooting, and naturally every industry would not be quite normal if that were not true; they want a duty or tariff on what they produce and offer for sale and free trade on their raw material used to make it. The realization that they must finally come to is that they must have a principle that applies to everybody and quit sharpshooting. Because you have radio now, and if you have to walk a hundred feet to your car and there is a radio in the car, some fellow sits by the radio and knows more about it than you know, because probably some additional information came over while you were walking to your car. You can't fool anybody any more. Many heads of industry are still trying to do it, so they trade each other down the river, and finally they are all down the river. They are at the moment, all industry at the moment is dependent on the whim of the Bureau official. He could make a trade in the morning and trade an investment right out from under you. Well, under that condition, is that conducive to private investment?

Mr. LUND. No.

Well, to mention some of these other potential fields of importance. The development of chromium and molybdenum and "cermets," for instance (a combination of metals and ceramic materials that will withstand high temperatures, to protect metals from oxidization, let's say, at high temperatures), are very important fields of research.

Senator MALONE. I was going to ask you if columbium and titanium might be a case in point. You have these minerals that are combined and are to a certain extent substitutes for columbium, do you not?

Mr. LUND. Of course, titanium is a substitute for columbium in stabilizing stainless steel; yes. The British and Europeans have used that for a long time, and the development of this extra low carbon stainless steel has been helpful in reducing the consumption of columbium, because there is less carbon in the steel to stabilize in the first place, and some of these very low, extra low carbon stainless steels can be handled, I think, and welded for some uses about as well as the columbium stabilized stainless.

Senator MALONE. Well, this tantalum in a combination or a substitute to a certain extent is a case in point.

Mr. LUND. Oh, yes; I see what you are suggesting there. The combination of tantalum and columbium rather than just columbium itself. That has also been a consideration; yes.

Senator MALONE. Now, we had testimony from one engine company, Pratt & Whitney, I believe—at least it is in the testimony that is published, and we will correct this testimony as you will correct yours.

Mr. LUND. Yes.

Senator MALONE. Testimony that they could make jet engines without columbium, which was very interesting to me, and they stood their ground.

Mr. LUND. Yes.

Senator MALONE. Some thought that they probably wouldn't be quite as good and wouldn't stand up under the combined heat and pressure as well, but this witness was a good witness.

Mr. LUND. Some of these companies have done wonders, too, in substituting, let us say, lower alloy content steel for such critical ma-

terials as iconel and iconel X in places that are subject to extremely high temperatures, and coating those alloys with ceramic coatings. They have done a lot in reducing the critical mineral requirements in this way, too.

Well, I will expand on some of these other ideas, if I may when I review this transcript.

Senator MALONE. I hope that you will take this as a very serious job, because this committee must rely on organizations such as your own. I hope that with our continued hearings after the first of the year we can submit another report through our own full Committee on Internal Affairs in the Senate that will be an addition to Senate Report 1627. In order for it to be helpful it must be entirely factual, and any vision that you can paint in a practical manner of the things you think that the Congress of the United States, that only the Congress can do, will be very helpful to us. I will say this to you, we had no difficulty in raising the depletion allowance on 31 minerals from 15 to 23 percent. Senator Byrd and Senator George think well of this committee so far, and I hope we can maintain its reputation. When I said that the reason, in my opinion, that we were about to have petroleum running out of our ears was because we had 27½ percent depletion allowance, they could use it for drilling a number of dry holes till they found new fields——

Mr. LUND (interposing). You are absolutely right.

Senator MALONE. And if we put increased depletion allowance on minerals so they could spend the money in searches for these materials—I mean laboratory work, too, then in my humble opinion we would increase the national security status of the United States of America. I will never forget what Senator George said: "We do not know very much about this subject. I suggest that we have our staff get in touch with Senator Malone's staff"—which meant George Holderer, Jerry Adlerman and others that were helping us—"and come back with the information, and we consider it." They came back in 3 or 4 days, and I complimented the staff, even better than we had at that time. They read off the 31 minerals, and the question in each case was, "Will this help?" and my answer was either I thought it would, in the case of lead and zinc and many other minerals, and it might in the remainder, but if it didn't, it doesn't cost anything. In some cases you might even increase the production to the point where the increased depletion allowance would furnish more taxes than a small allowance. Harry Byrd and others entered right into the conversation and it was a unanimous thing right away. It was the first offer that had been made to help the mining industry, generally considered, in two decades.

I tell you that to show you the attitude of Senators and Congressmen when they know they are right or think they are right. I have no doubt that all the money that is necessary, not available for good reasons from private industry because of lack of incentive at the moment, would be made available. We recommend $50 million a year, which may be only a start, but they would certainly make it available for national-defense purposes, and perhaps go even further, if it would increase the economic stability of the country, the economic structure of the country. Many Members of Congress, I am sure, believe as I do, that you can shake the economic structure of this country by making it advantageous to produce the material in foreign

nations, and shipping it in, causing unemployment and moving your civilian employment then to a war economy, which is nothing at all in case of a depression; and it is that entire field that this committee is directed to investigate by Senate Resolution 271, continuing its work, and, as I said before, the research institutes, of which yours is a very important sector, have the initial investigative field as a part of this ball team.

Mr. LUND. Well, fine. We certainly want to be considered as a part of the ball team, Senator, and I can certainly get any help needed at Battelle to expand this statement as desired.

Other examples of strategic mineral problems that might be solved in part, at least, from research presently underway include: (1) making synthetic quartz crystals, (2) making synthetic mica, (3) development of aluminum antimonide and silicon for rectifier or transitor use as a partial substitute for germanium, (4) recovery of fluorine from phosphates, (5) use of zirconium in place of tantalum in chemical equipment, and (6) use of titanium as a substitute for stainless steel (strategic nickel and chromium) in many applications.

A few examples of research problems that might be pushed harder in order to help solve strategic mineral problems are: (1) improvement of geophysical and geochemical exploration techniques, especially as applied to metals (long-range benefit); (2) improving methods for drilling rock (long-range benefit); (3) recovery of manganese from basic iron, from open-hearth slags, and from low-grade, domestic ores; (4) recovery of nickel, chromium, and cobalt from laterites; (5) extension and perfection of ion exchange processes as applied to extractive metallurgy; (6) extension and perfection of solvent extraction processes as applied to extractive metallurgy; (7) recovery of values from slimes in ore beneficiation; and (8) development of satisfactory material, with higher availability, as a substitute for tungsten in HVAP projectiles.

Senator MALONE. I would like very much to have it.

Now, does Mr. Richardson care to make a statement or does he have a statement he would like to submit?

Mr. RICHARDSON. Well, I would do nothing but substantiate what Mr. Lund has said here. There are possibilities, I believe you mentioned some of them, for example, columbium; you know, we do have scattered low-grade deposits—there are some in Canada—which we happen to be working on.

Senator MALONE. There are some in Idaho.

Mr. RICHARDSON. And some in Idaho, and if you will spend the money the columbium can be recovered—there are no suitable processes as yet for some ores that might ease the situation. The same thing, I think, applies to chrome and manganese. This is only a substantiation, I think, of what has been said as to the status of research and what can be done. I think it would be repetition for me to go into the same thing.

Senator MALONE. Well, my field of engineering for 30 years was in the construction of dams and the roads and irrigation districts and flood control, powerplants. It is an entirely foreign field to me when you get beyond the primary metals, but they do say that I am the only practicing engineer that was ever elected to the United States Senate, and at least I can understand some of it.

So, if the committee can present to the Senate understandable information that points to progress in this country, stability of the economic structure and greater security, then I feel we will have done our work. However, we must have producers like Mr. Howard Young, whom you heard testify this morning; we must have present research people and scientists, like your own organization; we must have the engineers, consulting engineers in special fields, with information such as that we turned up with from the Bureau of Mines, and from those engineers who spend their lives in certain areas of minerals. It was astounding, and it astounded some Members of the Senate. It was quite different from the information we have been fed from the national resources report, and from the Paley report. Now, I think Mr. Paley is outstanding in his field, but he said in answer to direct questions, and we quote him in our digest, that he did not know anything about critical materials, and he did not believe now that many of the recommendations they made at that time would work. We closed on that.

Mr. LUND. With respect to that report, I did want to say just this, that we recognize only too well that a lot of the features in this report are highly controversial, but I think that a lot of the information that dealt with the role of technology in the future of minerals, in extending supplies of minerals in the future—and there was one, I think it was volume 4, that dealt specifically with this—I think there is a lot of good, sound information in that material. As a matter of fact, Battelle contributed 41 reports to the Paley Commission report along that general line.

Senator MALONE. Very fine. The things that they ended up with, however, were recommendations that they got from foreign nations across a major ocean.

Mr. LUND. It is highly controversial.

Senator MALONE. I don't think it is even controversial. I think the decision would eventually destroy our country. What we want to know is how self-sufficient we can become in an area which we can defend when the chips are down, and then when we begin to win again and regain control of the air over Africa, Asia, and Europe, then we are in the running again. But, if we lose it in the meantime, the friendship of the nation 3,000, 5,000 miles away does us little good, simply because they at the moment control the deposits of the materials. It doesn't make sense. Trade with all the world on the basis of fair and reasonable competition, then go to work and forget about directing the operations of 2½ or 3 billion people. We are going to be pretty lucky if we direct our own, I think.

I appreciate very much, speaking as chairman of the committee, your appearance here, and we will look forward with great pleasure for your report.

Mr. LUND. Senator, you can count on Battelle's full cooperation.

Senator MALONE. Thank you very much.

Mr. LUND. We have appreciated the opportunity of appearing here.

Senator MALONE. Glad to have you.

Now, Mr. Fred Lynn is here. Fred Lynn, will you come forward.

STATEMENT OF HAROLD FREDERICK LYNN, CONSULTING ENGINEER, LOS ANGELES, CALIF.

Mr. LYNN. Senator, my testimony was so much in line with what you have already stated, I think that I will merely reiterate it, and I think give it far better in manuscript form. It deals principally with manganese, and the necessity of research on all of these subjects, but feeling that there are others that could testify to the subject of conversion and replacement better than I could, I left that subject to others more qualified to do so. I merely brought out one point that I think differs: there is no true substitute for anything, that those articles are established by technological preference and that all we do by making substitutes, in a sense, is merely to either use one not quite so qualified or we have one advantage in substitution, by creating substitutes that are better than the original ones that we were trying to substitute for. Other than that, there is no true substitution; we simply exchange.

Senator MALONE. Well, of course we understand that. The problem of the committee, under Resolution 143, as passed, put the arm right on our committee to determine the accessibility of these critical materials, materials that you do not produce enough of at the moment, the availability of the materials themselves or satisfactory substitutes or replacements, and your statement is exactly right, there is no substitute, but you do take molybdenum and tungsten and titanium and a lot of those materials, columbium, and to a certain extent some of them are interchangeable and some are more plentiful than others, and then, of course, as you say, sometimes you come up with a substitute better than the material itself; but I would suggest that since you heard this testimony that we send you from Washington a copy of your testimony, which of course is very brief at the moment. You have heard the other testimony, know the field in which we are interested, and you can take your time and prepare it for us.

Mr. LYNN. I have a manuscript form, and I will submit the manuscript form at the moment, so much as he can read, and I can make the corrections subsequently. I think in the interest of expedition that would probably be better.

Senator MALONE. All right, and then, if you want, we can send you a transcript of all of the testimony, but I think if we send you your own, and you have heard the remainder, you know what the committee wants, know the fields which the committee is interested in, and anything that you can give us that will be helpful, or reference to material that will be helpful, will be deeply appreciated.

Mr. LYNN. At this time I wish to point out one thing that was brought out in my written testimony, and that is when we are dealing in 10 percent manganese we are dealing in a material with a higher gross value than that of the San Manuel, for which the Government loaned or underwrote to the extent of $100 million. There must be something that would put some of our low-grade manganese deposits into profitable production.

Senator MALONE. Probably what we need is a little emphasis in the right places.

Mr. LYNN. Well, Senator, I wish to thank you.

Senator MALONE. Have you seen a copy of the report of the committee?

Mr. LYNN. I have not all of the copy. I have a copy of the summary of the committee report.

Senator MALONE. No. 1627?

Mr. LYNN. 1627, yes.

Senator MALONE. Well now, if you did, and you will take occasion to review it, you are an expert in your field—we so consider you—and we would like for you to make any suggestion that you would care to that the committee might very profitably review.

Mr. LYNN. I thank you for the opportunity. I have some very deep convictions on some of these things. It has been a pleasure again seeing you.

FURTHER WRITTEN STATEMENT OF HAROLD FREDERICK LYNN

In preface to my remarks on substitution, reclamation, conservation, and conversion of strategic materials in short supply, I wish to restrict my remarks at this time to the question of substitution. Others more qualified will, no doubt, present views on the other subjects, the last item being one little understood and only recently receiving the attention it deserves.

It is my considered opinion that there really is no true substitution of one material for another. In a free economy a material used for technological purposes is selected competitively:

1. It either is the only material that will do the job; or
2. If there be two or more choices, it more nearly meets the ideal specification set forth by the technologists than does its near competition; or
3. It costs less to use.

In the latter instance the end result is conserving labor and true capital in the normal processing sequence from raw material to use product.

If we accept the above premises and concern ourselves solely with the problem of supply of critical materials under a war economy, for those items in which our country is deficient or completely lacks, then I believe the following observations are pertinent. These critical strategic materials fall into the following categories:

1. Critical materials entirely absent in their natural state in this country;
2. Critical materials available but deficient in quantity;
3. Critical materials of adequate supply but which cannot be produced, or have not yet been produced competitively at world market prices, due to one or a combination of several or all of a variety of reasons.

RESEARCH NECESSARY

The long-term solution for the supply of the strategic items falling into the above categories is one of adequate fundamental and applied research of such broad base on a national scale that advantage is taken of the contribution of all the informed and willing people. The hazard of restricting fundamental research to intellectual cliques, whether governmental, educational, or in private capacities,

is that dangerous dogmas thereby may develop. Applied research can best be done by private enterprise given sufficient incentive. The short-term solution for the problem is, of course, a stockpile program sufficient to meet the maximum demands as conceived by the best military thinking.

Of the three categories listed above, we formerly included rubber and quinine in the first, but research has provided creative substitutes that are far better in many instances than the materials they supplanted.

Of the materials of the second category, mercury is an excellent example of the conditions that exist when we allow the control of the product to lie in hands other than our own. The European cartelized control of this important item of our economy has whipsawed the domestic industry. The cycles of short supply and high prices when American producers have been forced from the market and adequate supply and low prices when American mines are reopened under Government protection is a glaring example of the iniquities attendant upon our dependence of supply of critical strategic materials on sources beyond our control and without the zone of free marketing. The solution to the problems of this category is the development of better means of discovery. These items exist without our boundaries. We only need more of them.

Due to the dependence of the steel industry on its presence, manganese is the most important item of the category.

MANGANESE SITUATION

Because I am inclined toward the belief of those who fear the possibility of a long and destructive war, and believe in the saying that "there is no prize for second place in war," because the successful prosecution of modern war is based upon adequate steel supply and because steel supply is dependent upon available manganese of technological adequacy and because I know the subject fairly well, I wish to direct most of my remaining remarks to that strategic material.

Now, the manganese problem is saddled with two dangerous dogmas of defeatism and a philosophy of "one worldliness."

The dangerous dogmas propounded by intellectual cliques are:

1. There are no important deposits of manganese in the United States that can produce metallurgical grade manganese competitively on the world market;

2. There never will be a time when the consummation will be reached and that the manganese prog am is a waste of money.

The dangerous philosophy theorizes that manganese is one of the imports, not competitive with domestic industry, that will allow the rest of the world, by supplying us, to obtain dollar balances.

Let us examine the validity of this philosophy first; for the fallacy of the argument is evident with few statements. Our past and present suppliers of manganese are, in order of their importance in reserves and shipments to us, as follows: Russia, an avowed enemy; India, a confused and erratic neutral, with leanings toward our adversaries; Africa and Brazil, both in the throes of internal political upheaval and separated from the country by tenuous waterborne communication systems.

It seems beyond belief that we, in all conscience, jeopardize our very national existence by even momentarily entertaining this philosophy. It is just as sensible to have our munitions and armaments manufactured by our erstwhile enemies, and close our own, so that they too may get their required dollars.

In regard to dangerous dogmas, slightly more elaboration is needed.

While the world technology of manganese ore production is based on direct mining and shipping of finished product with only minor beneficiation, so were all metals at one time in their history thus produced, and more in point, so were iron ores in this country exclusively until recently.

Despite the dogmas most economists are willing to grant a 20-year supply at present consumption rate of 10 to 16 percent contained manganese grade. Now, even at world prices this is a gross value of $8.50 to $10 per ton in place for 10 percent ore. Technological developments in copper mining have allowed us to consider 1 large deposit with only $4.60 gross value of contained copper at 30 cents per pound, so economically feasible that it was underwritten to the extent of some $100 million by the United States Government. Of course, this $4.60 price does not include the value of the contained secondary metal, but neither does the price of $10 for the manganese ore give credit to the byproducts.

How is it then that copper technology is so much more efficient than manganese technology? Simply because the copper industry's halting growth was nurtured in a healthy, sympathetic atmosphere and protected until the domestic business was strong enough to stand on its own. Were the copper mines required to ship direct smelting ores to the domestic smelters now, we would be viewing that domestic industry with the same jaundiced eye that is used to gaze on the manganese deposits of this country.

All the manganese industry needs to be world competitive is an unvaried domestic program of long duration under a friendly and cooperative attitude by the Government. Then only will adequate capital be available to exploit the deposits on a scale that will provide efficiencies sufficient to make domestic production self-sustaining.

The present short-range program, halting in operation, fraught with conflicting rumors of termination and continuation, the request for application for long-term contracts when none are given, the conflicting statements coming from Washington, do not create an atmosphere wherein capital sufficient to meet the ends sought can be properly allocated by responsible people.

Despite these inequities and also despite errors in judgment by informed specialists, undoubtedly due to inadequate or erroneous basic information in the location of certain Government facilities, the inadequate program has done a great deal of good. As an example Artillery Peak has demonstrated that its ores may be brought to metallurgical grade by conventional beneficiation methods and that the area is bigger and that certain zones are of better grade than credited in the past. The cost of the program has been money well spent and the information received may at some time be the salvation of the country.

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In passing, it seems strange that this most successful deposit is threatened with shutdown while others less successful will continue to operate.

Given a long-term program it is conceivable that this area can produce metallurgical-grade manganese oxide at competitive prices when operations of adequate magnitude are inaugurated.

But Artillery Peak is not the only resource available. Cayuna and Aroostook deposits have extraordinarily large reserves.

Since these as yet can only be treated successfully by chemical methods, small-scale plants have been encouraged under Government auspices. It does seem incomprehensible, however, that the only chemical method evaluated from an economic standpoint by a disinterested research institution and found to have promise of producing high-grade manganese under world competitive conditions has yet to gain Government support (Resources for Freedom, vol. IV, pp. 48–49).

This, then, is a specific demonstration of the beneficial results of applied research. We can, if we will to do so, be free of foreign supplies of this gravely critical material, by further extending our research program and creating a friendly, protective, long-range program.

Finally, arguing from the particular to the general, our salvation in regard to critical strategic materials lies in the creation of a long-range research and development program. The fundamental research to supply creative substitutes for strategic materials in short supply, develop new methods of exposing hidden resources of the conventional materials, such as those ore bodies masked by recent detrital accumulation, this work to be done by Government agencies, educational institutions, and private or endowed agencies. Applied research can best be done by private enterprise using the tools and technology developed by the fundamental research, and encouraged by tax considerations. The cost of this research program cannot conceivably equal the cost of 1 year's cost of economic aid to any one of several European countries during the last few years.

In this age of widening scientific horizons with synthesis and mutations common practice, it is a brave man indeed who is willing to predict the limits of man's potential technical accomplishments. We can only find out by adequately exploring them. Perhaps by synthesis and metal mutations we may be self-sufficient in all of our required materials; at least we should try to be so.

Senator MALONE. We will stand in recess until 10 o'clock tomorrow morning.

(Whereupon, at 12:50 p. m., the hearing was recessed until Wednesday, September 22, 1954, at 10 a. m.)

STOCKPILE AND ACCESSIBILITY OF STRATEGIC AND CRITICAL MATERIALS TO THE UNITED STATES IN TIME OF WAR

WEDNESDAY, SEPTEMBER 22, 1954

UNITED STATES SENATE,
MINERALS, MATERIALS, AND FUELS ECONOMIC SUBCOMMITTEE
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
San Francisco, Calif.

The subcommittee met at 10 a. m., pursuant to adjournment, in room 261, Federal Courthouse and Post Office Building, San Francisco, Calif., Senator George W. Malone (chairman) presiding.

Present: Senator George W. Malone (chairman).

Also present: Jerome S. Adlerman, chief counsel of the subcommittee, and George B. Holderer, staff engineer of the subcommittee.

Senator MALONE. The subcommittee will be in order. Mr. H. A. Humble of the Dow Chemical Co. is here. Mr. Humble, would you come forward. Glad to see you, Mr. Humble.

Mr. HUMBLE. Glad to see you, sir.

Senator MALONE. Off the record.

(Discussion off the record.)

Senator MALONE. Mr. Humble, we are glad to see you here. You probably are familiar with the work that the Minerals, Materials, and Fuels Economic Subcommittee of the Interior and Insular Affairs Committee has already done, under Senate Resolution 143. There were 10 volumes of testimony, and then Senate Report No. 1627, a digest of that testimony, and including the recommendations and findings.

Now, the Senate saw fit to continue the work of this subcommittee under Senate Resolution 271, passed July 17, 1954, during the closing days of the 2d session of the 83d Congress. While the original resolution, Senate Resolution 143, passed on July 27, 1953, gave the subcommittee very wide latitude in determining availability of the critical materials in time of war and for our expanding economy and security, and, I believe, amply covered the situation, Senate Resolution 271 expanded the work, at least description of the proposed work, in detail, especially as it might pertain to substitutes and replacements for such critical material.

Now, the Dow Chemical Co. has a great reputation. I believe the Dow Chemical Co. to be one of the outstanding companies in the United States in the field of research; that they can do anything, practically, that can be done in their field. They have the men to do it, the know-how to take advantage of research of other organizations, like Government research, so I have asked you to come to give us any advice or information that you can in the field of strategic and

critical minerals and materials, with special reference to synthetic materials or substitutes or replacements for scarce materials. Will you please identify yourself for the subcommittee and give us any ideas you have.

STATEMENT OF HILARY A. HUMBLE, MANAGER, ELECTRO-CHEMICAL SALES, MAGNESIUM DIVISION, DOW CHEMICAL CO., MIDLAND, MICH.

Mr. HUMBLE. I am Hilary A. Humble, manager of electro-chemical sales, magnesium division, of the Dow Chemical Co., Midland, Mich. After listening to the testimony yesterday, Senator, and examining the review of previous hearings, I am not too sure how well my subject, that of material conservation through corrosion prevention, actually fits into your program, or how interested the subcommittee would be in such a subject.

Senator MALONE. Well, I think we will be very much interested. You see, what the Senate needs, in my opinion, is accurate information in the fields likely to be covered, or that could be covered advantageously by legislation.

COST OF CORROSION

Mr. HUMBLE. The committee is probably aware that the estimated annual cost of corrosion in the United States is approximately $6 billion and that as much as 40 percent of our 100 million tons of steel produced each year goes into the replacement of structures and equipment damaged by corrosion.

Senator MALONE. What percent?

Mr. HUMBLE. Forty percent. This cost is, of course, staggering and much of it represents an irreplaceable waste of our natural resources. American industry is becoming increasingly aware of this cost and of the need to conserve our resources. This is evidenced for example, by the rapid growth of an organization known as the National Association of Corrosion Engineers which although organized only a few years ago, now has approximately 5,000 active members.

This new awareness is also indicated by the fact that during the past several years many of our major universities have sponsored short courses on corrosion and expect to offer degrees in corrosion engineering in the not too distant future. As might be expected, this new interest has been accompanied by a greatly accelerated program of research designed to improve the corrosion resistance of existing materials and to develop suitable substitutes.

The corrosion engineer, therefore, today has at his command an increasing number of tools—these include protective coatings, corrosion-resistant materials, both metallic and nonmetallic, inhibitors, and cathodic protection.

All these methods have a definite place in corrosion mitigation. I would like to confine my remarks to that of cathodic protection.

Senator MALONE. That word again?

Mr. HUMBLE. Cathodic protection.

Senator MALONE. How do you spell it?

Mr. HUMBLE. C-a-t-h-o-d-i-c, protection.

As you know, metals corrode because certain areas develop a negative charge with respect to other areas.

Electric current flows from the negatively charged area out through the environment and back on at a more positive area. Corrosion occurs where the current leaves the surface, the corrosion attack being proportional to the amount of current flowing. For example, 1 ampere of current flowing for 1 year will corrode away approximately 20 pounds of steel.

CATHODIC PROTECTION

Now, cathodic protection is simply the application of direct current from an external source to, in effect, back out the local corrosion currents. Actually there's nothing new in the use of electric currents to protect metal surfaces against corrosion. Just how old this art is we don't know since it may well have been practiced even before its principles were clearly understood. However, it remained for Sir Humphrey Davy in 1824 working with galvanic anodes of zinc, iron, and tin, to discover and apply the method which we now know as cathodic protection. Davy originally developed this process as a means of stopping the corrosion on the copper sheathing of ship hulls. It was, however, only partially successful in practice since it interfered with the antifouling properties of the copper and was eventually rejected by the British Admiralty. Nevertheless, for almost a century thereafter, the use of zincs for ship hull protection was the major application, although there are scattered references to the use of cathodic protection in boilers and similar equipment.

As previously stated, cathodic protection is accomplished by making a continuous direct current flow from the corrosive environment to the metal structure which it is desired to protect. The current is introduced at an anode located far enough away to obtain reasonably uniform distribution of current. If the current is high enough, the corrosion attack on the structure can be completely arrested. These considerations limit the application of cathodic protection to the following:

1. The corrosive environment must be an electrolyte, that is, it must be able to conduct an electric current. The corrosion attack sometimes experienced in organic liquids can seldom be handled by cathodic protection due to their low conductivity.

2. The structure for which protection is desired must be completely immersed in or covered by the electrolyte so that all surfaces are accessible to the protective current. Electrical contact between structure and the external anode must be established not only through the internal circuit, but also through an external or metallic circuit as in the case with any battery.

3. Some minimum current must be applied to achieve complete protection. The current required to achieve protection varies widely depending upon the polarization characteristics of the local cathodes of the corrosion cell which are in turn dependent primarily on the metal involved and the conditions of exposure. For example, tests have been reported which show that titanium is easily polarized in seawater at an applied current of approximately 1 milliampere per square foot while copper requires 50 to 75 times more current under similar exposure conditions.

Senator MALONE. Why?

Mr. HUMBLE. Why?

Senator MALONE. Yes.

Mr. HUMBLE. Actually, it is due to the polarization characteristics of the metal concerned. Protection is accomplished when an equal potential surface is achieved on the structure you are trying to protect; that is, when the differences in voltage from point to point on the surface of the metal have been eliminated. This can be accomplished at lower current densities on some metals due to some inherent characteristics of the metal.

Senator MALONE. Is that related to the fact that the titanium in its native state is much more corrosive-resistant than the steel?

Mr. HUMBLE. That undoubtedly has a lot to do with it; yes, sir.

Senator MALONE. Go ahead, I didn't want to interrupt your trend of thought, but we have been led to believe that titanium is even more corrosive-resistant than stainless steel, and probably more corrosive-resistant than any known metal that we know how to make in quantity at this time.

Mr. HUMBLE. I believe that that is true. Titanium, certainly from the tests that I have seen, is more resistant to many corrosive agents than any other metal, with the exception of the noble metals such as platinum and gold, which, of course, are out of the question.

Senator MALONE. Yes. Now, I remember in 1 of our volumes, in 1 of the 10 volumes of testimony—perhaps it might even be mentioned in the digest, I don't recall if we went into it very much—the chemical industry appeared before the committee, and that was a surprise to me, to find that there was such a demand in civilian industry. Apparently only very few acids attack this titanium, and it is corrosion-resistant under sea water, and they would buy it at the present price if they could get it, to use in the chemical industry in very large amounts.

Mr. HUMBLE. Titanium would be very valuable for chemical process equipment.

Senator MALONE. And in the milk industry. That shows how ignorant I was about it, I never thought about the milk industry, and they said the same thing. So we came to the conclusion that at least there would be a tremendous civilian industry in the use of titanium for that very quality. In the interrogation, testimony showed that airlines could pay up to $70 a pound for it, because they would make it back in additional payload, due to the weight-strength ratio, so that the weight-strength ratio and the corrosive-resistant quality seemed to just put this metal right out front. I didn't want to divert you, but this is extremely interesting to me, and I am sure it will be to the subcommittee, because it seems to me that along with availability and accessibility of critical materials, saving the metal is as important as producing it, if it can be manufactured at the same or less cost and save the material.

Mr. HUMBLE. Yes. Well, that was our thinking.

Senator MALONE. It is availability and accessibility in time of war for our security and for our growing economy. That is what the Senate is interested in.

Mr. HUMBLE. Now Davy's discovery anticipated by some 100 years the technical and industrial advances needed to fully exploit cathodic

protection. This was due to the fact that satisfactory sources of impressed current were not available and that the only suitable galvanic anode, zinc, was practical only in electrolytes such as sea water where the conductivity is high.

Progress during the past two decades, however, has been rapid. The growth of a vast power distribution network and the introduction of the dry barrier layer rectifier afford a versatile, low maintenance source of d. c. current for impressed current applications. The introduction of magnesium galvanic anodes by Dow in 1945 made available a galvanic source of protective current having several times the driving voltage of zinc and greatly extended the scope of the galvanic protection method.

Magnesium has several inherent characteristics, apart from its availability, which recommend it for this application. These include high storage capacity for electric current, approximately 500 to 600 ampere-hours of useful current being realized for each pound of magnesium consumed, comparative freedom from polarization so that the current output remains constant with respect to both time and current drain, and a relatively high voltage. These same characteristics are equally valuable when magnesium is used to replace zinc in the ordinary dry cell. They result in a battery having a higher voltage and with double the life of a comparable zinc cell for most applications.

Senator MALONE. Are you telling us that magnesium is a substitute for zinc to a certain extent in the battery manufacture?

Mr. HUMBLE. I think that magnesium will largely replace zinc in the dry-cell industry in the not too distant future.

Senator MALONE. Well, there is an example, if that is true, of research making available critical materials. There must be a tremendous amount used in battery manufacture, and whether it is better than zinc or not, even if it would do as well as zinc in an emergency it would be a tremendous idea; wouldn't it?

Mr. HUMBLE. Yes.

Senator MALONE. That is what we are looking for.

MAJOR APPLICATIONS OF CATHODIC PROTECTION

Mr. HUMBLE. So much for the background. I would now like to describe some of the major applications of cathodic protection. First let's take the domestic water heater with which we are all familiar and which is probably the most acute and expensive corrosion problem confronting the homeowner today, costing an estimated $225 million annually. It is a problem which is rapidly becoming more acute because of the higher water temperatures recommended for automatic dishwashers and washing machines. For years these tanks were made of either galvanized steel or preferably some corrosion resistant metal such as copper, everdur, or Monel. The nonferrous tanks were the only type which could successfully withstand the corrosive water conditions encountered in New England and along the eastern seaboard. Beginning in 1946, however, the water-heater manufacturers began to apply cathodic protection using magnesium rods as a source of current. More recently cathodically protected vitreous enameled or so-called glass-lined black iron tanks have become increasingly popular. These will show greater corrosion resistance in almost any water than

the copper or monel tanks and, of course, at a considerable saving both in critical materials as well as cost to the homeowner.

Senator MALONE. I think you said a moment ago that the reason the galvanized tank did not stand up in the New England area, was that the water content of various chemicals corroded it faster?

Mr. HUMBLE. Yes, sir. It is actually the lack of mineral content that makes the tanks corrode faster, although that is surprising to the average person.

Senator MALONE. It is surprising because we know nothing about it, I mean in detail.

Mr. HUMBLE. From the standpoint of the manufacturer of these glass-lined tanks the application of cathodic protection not only resulted in the production of a more satisfactory product for the consumer, but also enabled him to effect the following savings in manufacturing costs.

1. The cost of the steel was reduced. Previously enameling grade iron was required because of the importance of avoiding glass coating defects resulting from a poor steel surface. This necessitated heavier gages than are normally employed in water heaters because of the lower physical properties of enameling iron. Since cathodic protection could be depended upon to prevent corrosion at pinholes in the coating, it was no longer necessary to buy premium grade steel.

2. The stainless steel spuds and washers were replaced by carbon steel.

3. One coat of glass is used instead of two since small defects are allowable.

4. Visual inspection is used instead of the elaborate electrical inspection procedure previously followed.

5. Production was increased because of the reduction in number of rejected parts.

So much for the water heaters. I would now like to discuss the application of cathodic protection to pipelines. These are, of course, extremely important in our present-day economy and would be even more so in the event of a national emergency. It is estimated that the corrosion of such lines costs American industry approximately $1 billion annually. Now pipelines are at the present time the major application for cathodic protection. Protection may be accomplished by burying magnesium anodes approximately 10 feet out from the line and connecting the magnesium to the pipe by means of a copper wire. In the case of a well-coated and wrapped line the anodes may be spaced as much as 5 miles apart and still provide complete protection. For bare or poorly coated lines, the anodes are spaced considerably closer together as might be expected. In some cases, a continuous magnesium ribbon is plowed in parallel to the pipe. These anode installations are customarily designed for 10-year life.

The savings both in material and in carrying capacity resulting from proper protective measures on pipelines are rather surprising. Pipelines laid without protection must be laid with thicker walls to avoid early perforation. When adequate protection is provided the wall thickness can be safely reduced some 20 to 35 percent. This is estimated to amount to 1,600 tons of steel per 100 miles of 8-inch pipeline. The reduction in wall thickness provides a pipe having a larger internal diameter having approximately 5 percent greater carrying

capacity. Based on the length of all the pipelines in the country, a 5 percent increase in capacity is equivalent to almost 50,000 miles of additional pipe.

The use of cathodic protection for marine applications is growing rapidly. As previously indicated, cathodic protection has been customarily used for stern frame protection on ships. Recently the entire submerged portion of the hulls on a number of ships has been protected using magnesium anodes which were distributed over the hull. The Canadian Navy has included cathodic protection on their specifications for all vessels in both their active and reserve fleets. Our own Navy is conducting extensive tests on cathodic protection, but have not as yet included this method of protection in any of their specifications. Our Maritime Administration, however, does employ cathodic protection for the preservation of the continuously submerged surfaces of the "moth ball" fleets.

In addition to the application previously discussed, cathodic protection is successfully used for the protection of condensers, heat exchangers, and similar equipment; lead-sheathed cable, transmission tower footings, buried storage tanks, and wharves and pilings in sea water. We estimate that in 1953 some 10 million pounds of magnesium were used for preservation of other metals.

Senator MALONE. Now, cathodic protection is interpreted, then, as magnesium anodes used in this connection, is that correct?

Mr. HUMBLE. Yes.

Senator MALONE. Anodes are used in the protection of the submerged surfaces of ships, then the cost of this protection is such that the prevention is an economic affair?

Mr. HUMBLE. It is economically favorable, yes.

Senator MALONE. Now, what does it do to the steel surface exposed to sea water that ordinarily would have to be scraped or cleaned or whatever they do to it every so often, and then, of course, replaced every so often because of the corrosion?

Mr. HUMBLE. It will afford complete protection for those surfaces that are continually submerged, it will eliminate the corrosion attack, and particularly the pitting type of corrosion, which is a major problem to the ship operator. The antifouling coatings still must be applied in order to prevent the growth of marine organisms, but the anticorrosive coating can be eliminated.

Senator MALONE. In other words, there is no corrosion when this is amply protected?

Mr. HUMBLE. No. The corrosion attack can be arrested.

Senator MALONE. Well, I don't know why you had any qualms about your testimony fitting in with what we want to know. I think it is a great asset and certainly an addition to the information the subcommittee needs.

Mr. HUMBLE. Thank you, sir.

Senator MALONE. Does that complete your statement?

Mr. HUMBLE. Yes, sir.

Senator MALONE. I would like to ask you a question for clarification. There are many alloys like the nickel alloys that are used partially to prevent corrosion. With this protection, those important alloys could be partially eliminated, could they not?

Mr. HUMBLE. In certain types of equipment, yes.

Senator MALONE. What, for example?

Mr. HUMBLE. It might be possible, for example, in perhaps a caustic evaporator, to use ordinary steel in place of nickel or nickel-clad steel.

Senator MALONE. Well, that is an example. Under what circumstances would it be impossible to furnish this protection that you have described, where you would have to continue to use these alloys?

Mr. HUMBLE. Tin and aluminum are subject to cathodic corrosion. These metals being amphoteric are corroded in certain environments by the application of an electric current.

Senator MALONE. It has the opposite effect?

Mr. HUMBLE. Yes.

Mr. ADLERMAN. Have you estimated the amount of nickel you can save by these uses?

Mr. HUMBLE. I don't know how you could go about it.

Mr. ADLERMAN. You would eliminate the use of Monel metals in heaters?

Mr. HUMBLE. In water heaters, for example, that could be eliminated.

Mr. ADLERMAN. And there is quite a large amount of nickel used in Monel?

Mr. HUMBLE. Monel contains, I believe, 70 percent nickel.

Senator MALONE. Nickel is a very scarce metal; not scarce in terms of amounts, but it is a very strategic metal. It is known that there are very large deposits of complex ores in Cuba, of nickel and chromite, and we believe that in a very reasonable time it might well be that these metals will be made available there. But at the moment any nickel saved, or a method of saving it during an emergency would be very helpful.

Mr. HUMBLE. Yes, sir.

Senator MALONE. Now, this is very interesting to the chairman of this subcommittee. Would you give us some idea of how widely used this method is at the present time in our Navy, in the armed services generally, and in fields that use a considerable amount of these so-called critical metals?

Mr. HUMBLE. It is certainly generally accepted. In a recent article by Dr. Uhlig of M. I. T. he pointed out that cathodic protection was probably the one sure way by which the corrosion attack could either be eliminated or the velocity of attack reduced to substantially zero. Its principal application to date has been in the pipeline industry, but it is being more widely used in the chemical industry, particularly in the chemical plants which are springing up along the seaboard, and which are using sea water as a coolant.

Its use for the protection of ship hulls is pretty much in its infancy. There are, I would guess, perhaps 30 to 40 ships which have been protected to date.

It is having a better reception for the protection of the inside of tank ships, which are used to carry crude oil and petroleum products. The corrosion attack in those tanks which are used for ballast on the empty or the light voyage, is extremely severe, and cathodic protection has been found to be probably the most economical and effective means of eliminating that attack.

Senator MALONE. Could you give us some comparison in costs?

Mr. HUMBLE. Well, let's see; in the protection of tanks on oil tankers, I believe that the cost of applying a suitable coating is roughly a dollar per square foot; cathodic protection can be applied for roughly 5 cents per square foot.

Senator MALONE. Five cents?

Mr. HUMBLE. Yes.

Mr. ADLERMAN. How long would that last?

Mr. HUMBLE. That is 5 cents per square foot per year.

Senator MALONE. And the other is a dollar per square foot per year?

Mr. HUMBLE. A suitable coating, such as Saran, would be expected to last for 4 to 5 years.

Senator MALONE. Thank you very much Mr. Humble. You have been very helpful and very interesting.

(The following was submitted by Mr. Humble:)

THE PREVENTION OF CORROSION USING MAGNESIUM ANODES

It has been estimated that the annual cost of corrosion to the United States is in excess of $6 billion, and that as much as 40 percent of the 100 million tons of steel produced each year is used for the replacement of structures damaged by corrosion. During the past two decades industry has become increasingly aware of both the cost of corrosion and the need to conserve our metal resources.

Cathodic protection is one of the methods used to combat corrosion, in which a direct electric current flows from an external electrode to the structure for which protection is desired. The current can be supplied by galvanic anodes such as magnesium or zinc, or by rectifiers. The method is limited in its application to structures which are either buried in the ground or immersed in water.

Its principal use to date has been for the protection of underground gas, oil, or water pipelines. The corrosion of such structures are estimated to cost American industry $1 billion annually.

Cathodic protection is being used extensively for the protection of domestic water heaters, the replacement of which are estimated to cost the American homeowner over $225 million a year.

In the marine field, cathodic protection has historically been applied for the protection of ship stern frames using zinc as a source of current. Recently complete protection of the submerged surfaces of ship hulls has been accomplished using magnesium anodes. The Canadian Navy have adopted cathodic protection for the complete protection of their ships as a standard operating procedure. The method is also employed by the United States Maritime Administration for the protection of their mothball fleets.

Senator MALONE. We have Dr. F. A. Rohrman, of the University of Colorado, on corrosion. Dr. Rohrman, would you come forward, identify yourself for the record, and just proceed in your own way. This testimony has been very interesting up to now.

STATEMENT OF DR. F. A. ROHRMAN, EXECUTIVE DIRECTOR, ENGINEERING EXPERIMENT STATION, UNIVERSITY OF COLORADO, BOULDER, COLO.

Dr. ROHRMAN. I am executive director of the engineering experiment station at the University of Colorado, and also chairman of the committee on research at the university. For the last 25 years I have been working on corrosion problems, both in the theoretical side and as a consultant for various corporations on more practical problems. It is a problem that is enormous. I certainly will verify all that the last witness has said about its enormity; $6 billion is a conservative figure as to how much it costs us.

Senator MALONE. At 40 percent of the annual production of 100 million tons of steel, it is a terrific thing.

Dr. ROHRMAN. It is.

Senator MALONE. I had no idea it amounted to that figure.

Dr. ROHRMAN. That is right, just for replacement of steel that has corroded, that is what it costs the industry, and, of course, there are many ways to protect against corrosion, of which cathodic protection is one, but cathodic protection has its limitations. It can be used only where the steel is underground or in certain waters.

Senator MALONE. Yes, that was the testimony.

Dr. ROHRMAN. It cannot be used where it is above the ground or in certain chemical solutions.

Senator MALONE. Because you have no current?

VARIOUS PROTECTIONS AGAINST CORROSION

Dr. ROHRMAN. Well, not only that, because in certain chemical acids, for instance, the corrosion is so severe you just can't apply it, so you have to use other methods; to give you an idea of some of these methods, the earliest ones, of course, were painting and covering with tars and asphalts. Now, we have various paints, which I am sure that the painting industry knows a great deal more about than I do, as to which are the most efficacious for certain weather conditions, and also for certain kinds of metals. Certain paints are applicable and certain ones or not applicable.

Then, we have the means of making different alloys. That is, the earliest iron, certainly, is nothing compared to what the iron is today. You introduce a little copper or a little nickel in some iron, and it makes a great deal of difference as far as corrosion in atmospheric conditions.

Then again, if you had considerably more nickel or chromium, or both, you get what we call the stainless steels, and, of course, they are very resistant, not only to the atmosphere, but to many weak acid solutions, and so forth.

This cathodic protection is a problem that is rather recent in its use. It is being applied by the petroleum industry probably with greater attention than any other group. They are doing a wonderful job on this. They have their own staffs that are studying it constantly, so the petroleum industry and water purification industry are relying upon cathodic protection, and because of that, they rely a great deal, as the last witness said, on magnesium, which is good, but in some instances magnesium doesn't work; they say that zinc is better, or even an applied current through carbon anodes is better than either.

Then, one of the large aluminum corporations has retained me to study the effect of making aluminum possibly useful. There are certain reasons why aluminum might be even better than anything, and by putting alloying agents in aluminum it might be made just as good as magnesium or zinc or the applied current.

Now, this whole corrosion problem comes down and resolves itself down to one thing, and that is: Where do the universities come in? Then is the need for basic and fundamental research on all these problems. To give you an idea, some time ago I had a problem which I thought would be very desirable for Government sponsorship. You see, we have the Office of Naval Research and the Air Force Applied

Research, the Army Ordnance, and so forth, so I had a problem I presented to them which might be a good one for them to finance, as they do finance lots of research. Well, they came back and said this problem is too applied, too practical in nature for us to sponsor. The result is, I went to several steel companies with the same problem. They said it is too theoretical, so there you are. We run into those things where we can't find sponsorship for a problem which we think is very desirable to be worked out.

NEED FOR RESEARCH

Senator MALONE. Dr. Rohrman, I presume you have seen a copy of our report?

Dr. ROHRMAN. Yes, sir.

Senator MALONE. We recommend there—and it was more of a shotgun recommendation rather than knowing in detail what amount of money would be necessary—but we did recommend $50 million annually that might be appropriated for such research, to be used, utilized by the Government in cooperation or connection with universities or companies.

Dr. ROHRMAN. As I mentioned, the petroleum industry have large groups of men just working on corrosion problems that are allied to the petroleum industry. The Dow Chemical, du Pont, other large chemical companies, have groups that are devoting their attention just to their own particular problems of corrosion, which is as it should be.

Senator MALONE. It is an economic problem.

Dr. ROHRMAN. Yes; it is an economic proposition to them, and the application of these problems will die on the vine unless you get some fundamental attention to the fundamental problems which are finally applicable to the applied problem, and that is where the universities come in: that is, they study something that might be quite vague to the problem; suddenly somebody snatches it, says, "Well, here is the answer to this, what we have always wanted." That is the thing we need, a great deal more fundamental research in the universities on just problems pertaining to corrosion.

Senator MALONE. Someone referred yesterday to a stockpiling of research. Every once in a while you come up with something, and then you have it in the offing, for a time of emergency whether economically feasible or not.

Dr. ROHRMAN. That is right. It was the obtuse and vague problems in the field of atomic energy which have made the atomic bomb possible. The snatching of those ideas and applying them can also be done for the problems in corrosion. There are a lot of fields not yet studied in the lines of corrosion, which should be studied, and they may result in answers that will never be used, but then again you can never tell; so that is what I say, it is so important that your committee be cognizant of the importance of fundamental, basic research in corrosion, so that the material may be utilized some day for industry and the Government.

Senator MALONE. Are there many universities besides your own that are paying close attention to this problem now?

Dr. ROHRMAN. Yes; I should say there are probably 20 devoting a great deal of time to corrosion.

Senator MALONE. Will you list those universities for us?

Dr. ROHRMAN. To list some of the universities outstanding in their work on corrosion, we can alphabetize them with the professor's directing such work as follows:

Boston College: Prof. Andre J. deBethune
Case Institute of Technology: Prof. R. C. Weast
Marquette University (Milwaukee): Prof. Harold F. Haase
Massachusetts Institute of Technology: Prof. H. H. Uhlig
Missouri School of Mines: Prof. M. E. Straumanis
Ohio State University: Prof. Mars G. Fontana
Rensselaer Polytechnic Institute: Prof. George J. Janz
Texas A. and M. College: Prof. J. D. Lindsay
University of California: Profs. I. Cornet and D. R. Loper
University of Delaware: Prof. Lewis W. Gleekman
University of Houston: Prof. Joseph R. Crump
University of Illinois: Prof. Ray Wainwright
University of Oklahoma: Prof. John P. Roberts
University of Oregon: Prof. Piere Van Rysselberghe
University of Texas: Prof. Norman Hackerman
University of Wisconsin: Prof. Wayne K. Neill
Washington University (of St. Louis): Dean Lawrence E. Stout
Yale University: Prof. W. D. Robertson

Senator MALONE. Do you have any interchange of information?

Dr. ROHRMAN. Oh, yes.

Senator MALONE. Any meetings?

Dr. ROHRMAN. Yes.

Senator MALONE. Or methods of interchange?

Dr. ROHRMAN. Oh, yes. We have two national societies devoted to that. One is, as previously mentioned, the National Association of Corrosion Engineers, and the other is the American Electro-Chemical Society, or what is now called the Electro-Chemical Society; and these societies meet quite often. They have their subsections, which meet quite often, and these professors and the men in industry contribute papers of discussions on just these problems. This thing is completely polypartisan, this whole subject is, and the fundamental information is completely polyusable by everybody, and for that reason there is no retention of data as far as I can tell.

This is just a waste, just an economic waste, when you consider $6 billion that is just down the drain. It just requires more manpower to make it up; where you recover a metal from the soil, nature just tends to bring it right back again and tries to use every effort it has to get it back into the soil the way it was, and that is what we are constantly fighting, nature.

Senator MALONE. You not only have to perfect the method of mining the material and processing it, but then you have to perfect methods to fight its return to its initial state?

Dr. ROHRMAN. That is right. It is a double-barreled fight, exactly.

Senator MALONE. I think this is new, it is new to me, and I am sure it will be new to the subcommittee, that there is as much activity as there is in this field.

Dr. ROHRMAN. It is of rather recent origin, this work. The history of getting the metals out is very ancient, of course, but the history of keeping metals from going back to the soil is relatively recent.

Senator MALONE. Of course, you are perfecting the methods continually of getting them out. At the American Mining Congress that started meeting Monday, and will continue through this week, there are many experts in that field.

Does that complete your statement?

Dr. ROHRMAN. I could mention a few other things; for example, I could mention how lacquers are saving economic materials. For a while the tin can, you know, which everyone is familiar with, was actually a sheet steel covered with tinplate, and that was used for our foodstuffs; now the lacquers have come along, the various plastic materials have come along and enabled us to use much less tin in a tin can, and it is just as good as it has ever been, if not better, so there is a way that our natural resource which we have too little of, tin, is being conserved.

(The following was submitted by Dr. Rohrman:)

CORROSION, AN ECONOMIC ITEM INVOLVING BILLIONS OF DOLLARS

By F. A. Rohrman, Executive Director, Engineering Experiment Station, University of Colorado, Boulder, Colo.

INTRODUCTION

The only metals found free on the earth's surface are those like gold, silver, copper, and platinum. Iron sometimes is found free, but only as meteoritic iron. Most of the metals so useful to man are not found as the free metal; consequently they must be reduced from their ores so that they may be used by man; such metals are iron, zinc, aluminum, magnesium, lead, etc. The moment such metals are produced and used in their free state, the forces of nature attempt to rust, corrode, oxidize, and convert them to their natural or original state as first discovered. The destructive forces of nature, though sometimes slow in action, are quite relentless and powerful. It is indeed unfortunate that those metals most useful to man are also the most susceptible to these destructive forces of nature.

Nearly everyone is cognizant of rust and corrosion, yet does not appreciate the extent of the depredations involved. With the gradual rise of living standards, one's appreciation of corrosion is enhanced. Everyone is familiar with the rusty can, hot water heater failures, and the appearances of so many sheet-steel buildings that give the visions of economic degredation. Today, experts in this field can prove that corrosion costs the people of this country around 6 billion dollars a year. It can be shown that over one-third of all the steel fabricated into useful materials and equipment is made simply to replace the equipment and materials which have been rejected due to corrosion. The petroleum processors of this country state that the cost of gasoline is approximately 1 cent higher because of corrosion's demands. It has also been estimated that underground corrosion of pipes and conduits costs this country $1 billion yearly.

COSTS OF CORROSION ATTRIBUTABLE TO MANY FACTORS

The final tab which corrosion hands us may be the accumulation of many evident and some hidden costs. These costs may be tabulated as follows:

1. Costs of equipment, or plant replacement.
2. Loss of time, or upset production schedules caused by shutdowns.
3. Cost of inspections and maintenance.
4. Cost of protective means other than maintenance.
5. Loss of product or conveyed material.
6. Costs of additional power to maintain flow of gas, fluid, or heat.
7. Contamination or discoloration of product, with associated loss in value.
8. Loss of artistic value, or eye appeal.
9. Cost of research to combat corrosion.

THE PREVENTION AND MITIGATION OF CORROSION

Having recognized the enormity of the corrosion problem, the next thing to consider is what is being done today about corrosion and its mitigation.

While the destructive nature of corrosion has been known for centuries, as the Bible speaks of it, and Pliny, Chaucer, and others mention of its force, the actual, organized effort to eradicate corrosion is of recent origin. Many of our

progressive chemical, petroleum, and steel corporations have had informed or trained personnel directing corrosion countermeasures for years. A large number of National, State, and municipal laboratories are engaged on corrosion problems. Many colleges, universities, and foundations contribute useful information every day to this subject. These efforts have been accelerated and expanded in the past few years.

There is a large technical society organized for the purpose of disseminating corrosion information, study, and its mitigation or prevention. This society, the National Association of Corrosion Engineers, was organized in 1944, and now has a membership of over several thousand members with several hundred corporations added to special memberships. Practically every technical and engineering society has special appointed committees devoted to corrosion. Every large industry today has special staffs charged with corrosion prevention.

The mitigation and prevention of corrosion has been directed toward:

1. Protective coatings (paint, tars, and lacquers).
2. Protective plates (tin, zinc, and aluminum plates or coats).
3. Alloys (stainless steels, bronzes, brasses, etc.).
4. Treatment of corroding media (boiler water additions, phosphating, and inhibitors).
5. Cathodic protection (the application of devices and materials which reverse nature's tendencies).

With the increasing complexity of our manufacturing processes and the popular demands for more mechanical devices and different consumer materials, it is only natural to expect that the opportunities for corrosion are greater each day. The need for more research and application in these matters is certainly indicated. The production and accumulation of strategic metals and their products can be nullified if the forces of corrosion are permitted to act against them.

Senator MALONE. We appreciate your coming here.

Dr. ROHRMAN. Glad to be here.

Senator MALONE. And of course we hold these hearings on the occasion of the American Mining Congress meeting, because many of you like to attend these meetings and it saves your time and our time and money.

Dr. ROHRMAN. Thank you, sir.

Senator MALONE. Thank you very much.

Mr. S. M. Shelton, will you come forward, from the Bureau of Mines. Mr. Shelton, I am glad to see you.

Mr. SHELTON. Very glad to see you, sir.

Senator MALONE. The reason goes a long way back. Do you remember John Koster?

Mr. SHELTON. Yes, sir.

Senator MALONE. Who worked under you in the University of Nevada in working out and perfecting the protection of electrolytic manganese, and your name has been familiar to me for 20 years. We must have met before, but we have never really got acquainted.

Mr. SHELTON. Yes; I was in Reno for 3 years, I guess, in those days.

Senator MALONE. You were located in Missouri at that time.

Mr. SHELTON. Well, I left Reno for Missouri.

Senator MALONE. Yes, and then John Koster was your representative there for some time.

Mr. SHELTON. Well, John Koster moved to Boulder City.

Senator MALONE. Yes, later.

Mr. SHELTON. Later. You know, in Boulder City they expanded the work on electrolytic manganese. In Reno we made the first hundred pounds of electrolytic manganese to show that it could be done, and then they made a pilot plant to find out how much it would cost.

Senator MALONE. Where is John now?

Mr. SHELTON. I think he is back in Indianapolis. That is the last I have heard of him.

Senator MALONE. Well, Mr. Shelton, I am very glad to have you appear before this subcommittee. As time goes on, lots of water has gone under the bridge since I was preparing an industrial encyclopedia of the 11 Western States, Alaska, Hawaii, and the Philippines. I insisted at that time that we have a brief of electrolytic manganese, believing that it would find its place in industry and make available, through low-cost power, or as low a cost as we could get, make available many lower grade deposits of manganese for commercial uses. John Koster wrote the brief that is in the report, and I have read that the industrial encyclopedia is being used in laboratories and in many high schools. It was not kept up to date as we originally intended, but the basic information is just as good as it ever was, and I want to express my appreciation of that assistance we had at that time. If you wanted to, you could tell us something about the uses of this electrolytic manganese and its possibilities while you are here.

TESTIMONY OF STEPHEN M. SHELTON, REGIONAL DIRECTOR, REGION II, BUREAU OF MINES, ALBANY, OREG.

Mr. SHELTON. Well, I still believe it will expand even more than it has. There is a company in Tennessee, I believe, that is making it at the rate of 20 tons a day.

Senator MALONE. I am under the impression that Union Carbide plans to make electrolytic manganese, too. If you remember, yesterday a man testified to the effect that they could make manganese stainless steel by substituting manganese for nickel.

Mr. SHELTON. Electrolytic manganese essentially makes that possible, because it is a pure metal that can be added.

Senator MALONE. How pure is it?

Mr. SHELTON. It is 99.99 pure.

Senator MALONE. That is just about as pure as anything gets, isn't it?

Mr. SHELTON. That's right. It has a little hydrogen in it, which they eliminate by heating, except for that it is about as pure as they can get it.

Senator MALONE. My impression is people said at the time that of course it could not be substituted, or would not be on account of economic conditions, for the regular use of ferro-manganese. But that seemed to fade out into the realm that the furnaces and the methods of making steel were already established, and, unless economic conditions changed, there would not be any great sudden change, but the electrolytic manganese could be used if necessary.

Mr. SHELTON. I don't think there is any doubt about it.

Senator MALONE. Well, I think you have done a great job in that research, and speaking as one member of the subcommittee, I appreciate the possibilities in research. That is one field that this subcommittee is covering in each particular subject, as to possibilities of improvement in alloys and substitutes, replacements, and that is the reason the subcommittee finally said flatly in their recommendation that we could become self-sufficient in the Western Hemisphere area.

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Mr. SHELTON. Well, Senator. Personally, I am convinced that our salvation is in strength, and that one of the prime requisites of strength is a healthy domestic mineral industry, and I think that the Bureau of Mines is dedicated in the direction of improving the technology of the mineral industry wherever we can toward building up a healthy domestic industry.

I am Regional Director of Region II of the Bureau of Mines that comprises the States of Washington, Oregon, Idaho, and Montana. We are doing work in there that I think fits in with the objectives, at least contributing something to the objectives that your subcommitee has in mind. I could enumerate a few things that we are doing. I think they would be of some interest.

BUREAU OF MINES RESEARCH

As you know, and I think you mentioned yesterday, in the State of Idaho we have tremendous black sand deposits, placer deposits, and they are being worked in cooperation with the Atomic Energy Commission. We have been developing these reserves, and they are very interesting. All of them are high in ilmenite. Most of them are relatively high in monazite. There are other sands that contain a mineral called euxenite. Euxenite contains uranium, columbium, a small amount of tantalum, yttrium, and titanium, just about everything we need, but is a very complex mineral, and we in Albany are trying to crack that mineral so its various and sundry components can be extracted.

Senator MALONE. That comes under the head of a complex section.

Mr. SHELTON. That is right.

To get back to the monazite, of course, it is the source of thorium for this country, and it is in the sand in relatively large quantities, but when you mine either one or the other or both of these minerals, you inevitably will get a byproduct, ilmenite. In fact, they have already built up a stockpile—not a stockpile, but a tailings pile of some 60,000 tons they couldn't help but build up because they were taking out the monazite.

We have been working on that particular ilmenite, a direct smelting to get a pig iron and a titanium slag. We have shipped the slag, I think we shipped 20 tons to Boulder City, and just recently we have been assured that the slag is equal to rutile.

Senator MALONE. Which we are getting from Australia, and couldn't get a pound of it when the war started.

Mr. SHELTON. We are not even satisfied with that, though. Rutile is a source of titanium for making titanium tetrachloride, from which in turn we make titanium sponge; but it is a sluggish mineral. When you make the chloride you have to continually pump heat into it. It is costly. Now, we think and we hope that we can make that slag so that it would be exothermic in its reaction with the chlorine and we wouldn't have to pump heat into it. In other words, here we are making a substitute, which isn't a substitute exactly, because we hope it will be an improvement, and for that reason I don't like the word substitute so much because these different materials have their own characteristics and their own possibilities, I would almost say their own personalities.

We are really discovering a new material itself. This opens up a new field, and in opening up a new field it calls for the additional

use of old materials. We have an expanded industrial economy. I believe today we are going through the greatest materials development period the world has ever seen. We sometimes feel we can't see the forest for the trees, but when we review the developments that have taken place in the past 20 years, it is absolutely obvious, and there is no reason to believe that developments will not continue.

Senator MALONE. I want to say something at that point. We have had many reports in the years over the last two decades, such as the National Security, National Resources Committee, the Paley report, and other reports. Now, the thing that irritated me almost always in these reports is that they would take the data from the Bureau of Mines and other reliable data and arrive at conclusions which have no real connection with the data. They have concluded that we have nothing in this country, we have to ship it all in. That is the general trend of thought, and they have propagandized the people of this country during the last two decades that we must protect these offshore areas, Africa, Europe, and Asia, because they are our only sources of these materials. Such speeches have been made by prominent people in this country. We protect Belgium because we get uranium from the Belgian Congo.

I believe that if we treated our people, producers in this country, taxwise half as well as we do foreign producers, uranium would be running out of our ears in 2 years.

RESEARCH ON MANGANESE

Mr. SHELTON. We are working on manganese to a lesser degree, I guess, in the Northwest, although our manganese resources are higher, probably, than they are in any other region of the Bureau of Mines. It is being produced commercially, of course, by Anaconda, and being mined by various companies. The General Services Administration has a stockpiling program. We are testing the ores to show how much the recovery would be, and the price, I think, is based on our tests. We are also working with manganese that is contained in highly siliceous ores, rhodonite, for example, and we have been able to smelt this rhodonite and get a very satisfactory commercial grade silico manganese, which is a commercial product. Now, the interesting thing about that to me is it completes the picture. We are at the point now where we can say from a technological point of view we can recover usable manganese from any known deposit.

Now, that is a broad statement and I must qualify it by saying, of course, that we can't necessarily do it at a profit, but I think that the Bureau of Mines should carry on its work in that direction as rapidly as it possibly can.

Senator MALONE. There is no question about it.

PROGRESS ON NICKEL RESEARCH

Mr. SHELTON. The work in Cuba on nickel deposits has possibly overshadowed to some extent the fact that we have in Oregon very substantial nickel deposits. One of them we know contains a minimum of 20 million tons of ore that will run 1½ percent nickel, I believe that is the cutoff point, and it hasn't been fully explored yet. There are several other deposits in Oregon and in northern California that are known to carry nickel. The Bureau of Mines has been working

on that. They did some initial metallurgical development work on it a year or so ago; M. A. Hanna Co. has obtained a contract influenced by the fact that we showed to them that the nickel could be smelted and recovered as ferronickel. Subsequently, they decided to use a modification or different process of smelting, but we feel that we established the fact that the nickel was recoverable by direct smelting. That has resulted in the building of a large smelter at Riddle, Oreg., and it is due to go into operation within a few months. I think they are making some initial test runs now.

Senator MALONE. What is the capacity in tons per day, or how would you compute it?

Mr. SHELTON. It is my understanding that the plant is designed to produce 7,000 tons annually of nickel as ferronickel containing 40 percent nickel. It is a substantial undertaking. I think the estimated cost is on the order of $21 million for the smelter and mining installation.

Senator MALONE. Same connection, a private company and General Services Administration?

RESEARCH ON ALUMINUM

Mr. SHELTON. Yes, sir. Some year or 2 years ago or thereabouts, we entered into a contract with Apex Smelting Co. to attempt the recovery of aluminum and silicon as a metallic alloy direct from clay by direct smelting. That turned out to be successful, and that company, in combination with American Smelting & Refining Co., built at Springfield, Oreg., a smelter to produce this alloy of silicon and aluminum that will probably run on the order of 50 percent aluminum and 50 percent silicon. About 25 percent of all aluminum produced is used as castings and most of the castings are silicon-bearing alloys, so the material could be a master alloy for making aluminum castings. It is certainly not a thing that would revolutionize the aluminum industry, but it just gives us another source of supply of aluminum in smaller quantities, using domestic clays.

Senator MALONE. Well now, there is no limit to the amount of aluminum clays that we have in the country if we eventually can make the proper use of them, is there?

Mr. SHELTON. That is true, sir.

Senator MALONE. It is just simply a question of economics and a question of converting the alumina in the clays, of extracting the alumina from the clays under a process of proper magnitude to make it available?

Mr. SHELTON. This is a slightly different approach, in that we don't attempt to extract alumina from the clays, we just feed the clay directly into the furnace and smelt it and pick out the metal. That is all it adds up to, but in doing that we get an aluminum alloy rather than the aluminum itself, and to be used as a metal it would require some purification.

Senator MALONE. That could be done?

Mr. SHELTON. I think it could be done. It needs a lot of work to do it, but it can be done.

Senator MALONE. You just utilized a direct approach?

Mr. SHELTON. No use beating around the bush.

Senator MALONE. There is no limit to the amount of aluminum clays in this country, is there?

Mr. SHELTON. No limit, no, sir.

Senator MALONE. So then we could say that as far as bauxite is concerned, this nation might become self-sufficient in the raw material from which you can extract aluminum, to make aluminum?

Mr. SHELTON. Well, I am no expert on the reserves of bauxite.

Senator MALONE. I am not talking about reserves of bauxite, but you wouldn't need the bauxite.

Mr. SHELTON. Technologically again, there is no reason in the world why we couldn't support any sized aluminum industry in this country from domestic materials, but again we go back to how much does it cost to get it out.

Senator MALONE. Now, as an example, when we were talking about depletion allowance, as a result of the work of the subcommittee, the Senate Finance Committee changed the depletion allowance on taxes from 15 to 23 percent on 31 minerals, including bauxite. There was an argument made on the Senate floor from factual information that was furnished a few years ago that there was a limited amount of bauxite in the country and therefore at present use it would not last very long. Of course, that is part of a fallacy that has been foisted on this country, for this reason. Engineers, when talking about reserves, mean the known amount that can be extracted at a profit. But, since these figures were furnished to this Senator, a method using bauxite containing more silicon has been developed and has approximately doubled the reserves of bauxite which could be extracted at a profit. Now all you have to explain to our legislators are the facts concerning these things you are doing. Our subcommittee was created to get this information. I don't understand all of this either although I have been in the engineering business 30 years. I have been in a different branch of engineering. There are many different kinds of engineers.

Mr. SHELTON. That emphasizes my contention that we are moving awfully fast in this field.

Senator MALONE. That is right.

RESEARCH ON CHROMIUM

Mr. SHELTON. If I can carry along, another job that I think we are doing reasonably well is a demonstration, I believe, that we can smelt chromites that are in this country—they are relatively low grade in terms of the iron-chromium ratio, but I think that we have shown very definitely that ferrochrome can be made from our chromite; that we have unquestionably enormous tonnages of chromite in this country, particularly in Oregon and Montana——

Senator MALONE (interposing). Northern California, too.

Mr. SHELTON. And California, yes, sir; excuse me. I am just thinking of the northwest region. And we also make what is known as ferrochrome-silicon, that is another ferroalloy consisting of iron, chromium, and silicon. It is used in stainless steel, for example, making a low-carbon steel. We believe by doing this that we can show that if the circumstances warrant it, we could supply our domestic needs of chromium from domestic ores.

Senator MALONE. You recognize the importance of the statement you have just made, I hope.

Mr. SHELTON. I hope so, and I believe I do, sir.

Senator MALONE. Because so many people contend that we have no chromite; that is, we haven't a grade that you can make ferrochrome, knowing that in our past experience and the past methods we needed a high-grade chrome, 40 to 46 or 7 percent with the low-iron content to make successful ferrochrome.

Mr. SHELTON. I will have to qualify that statement to this extent, sir; we could make a ferrochrome that would be probably somewhat lower in chromium than the so-called standard ferrochrome. I don't know why it couldn't be used as readily as standard ferrochromium because we are simply adding iron and chromium to the steel.

Senator MALONE. And the iron is there already.

Mr. SHELTON. Right.

Senator MALONE. Go ahead.

RESEARCH ON ZIRCONIUM

Mr. SHELTON. The Albany Station of the Bureau of Mines has grown large within the past few years, and a major reason for its growth has to do with the fact that we are in the zirconium business.

If you will bear with me, I would like to give a little history on this.

Senator MALONE. I would like you to do that.

Mr. SHELTON. The group of metals, there are three of them that are very similar in chemical properties: titanium, zirconium, and hafnium. They are very closely related chemically; they are different physically. That is, titanium is a light metal, zirconium has about the density of steel, possibly, just a little less; hafnium has about twice the density of steeel, something in the order of a specific gravity of 13.

Now, of course, the Bureau had done a whole lot of work on titanium, using the Kroll process, and it became quite evident that the same process could be applied to zirconium. Back in 1947 or thereabouts, the Atomic Energy Commission, and the Navy, were setting out to build an atomic submarine.

Senator MALONE. I watched it launch last year, or early this year, I forget which, in Connecticut.

Mr. SHELTON. Yes, sir. It was being pushed, but they came to a problem of a material to contain the power or the uranium, say, within the reactor so that you could get the energy from the uranium to the water which had to be heated up to generate the power. Now, that material had to have two characteristics: it had to be transparent to the so-called thermoneutrons that emanated from the uranium, and it had to be corrosion resistant at those very high water temperatures, and they were in a quandary. They could possibly have used stainless steel but efficiency would have dropped to a low figure; beryllium was an ideal possibility, but there wasn't any beryllium as a structural material; aluminum had the nucleonic properties but it couldn't stand the corrosion resistance. Prof. A. R. Kaufman, of MIT, in reviewing the possibilities of metals, ran across zirconium, which according to the figures available at that time wasn't particularly promising, but he looked into it and he found that all zirconium that had been made—and only a little bit had actually been

made—contained hafnium to the extent of about 2 percent and that was just enough to ruin it.

He reached the conclusion if you could separate the hafnium from the zirconium you would have a very good material, because zirconium was believed to be corrosion resistant. The only zirconium being produced then was by a very tedious, expensive process, that produced it at about $270 a pound. It was a laboratory curiosity and there was no known way of separating this hafnium and zirconium. We had studied this new process of reduction, and were just beginning to get it in a pilot plant stage, but no company wanted to tackle it on the meager information we had and nothing was known of the fabrication properties. So at that time I would say that the zirconium industry was a gleam in Captain Rickover's eye, but we started in.

Senator MALONE. He is one of my very good friends.

Mr. SHELTON. He is a very good friend of mine, sir. I've certainly enjoyed my contact with him for the last several years.

We started, expanded our operations to produce some metal to work with the hafnium metal without the separation. We set up a little pilot plant that produced about 60 pounds a week, and we made a ton of metal that way. In the meantime, Union Carbide & Chemical Co., at Oak Ridge, Tenn., looked into this hafnium separation work.

Senator MALONE. I have visited their operation.

Mr. SHELTON. Did you? And Batelle Memorial, and Iowa State College started in to investigating the alloying possibilities. Westinghouse, which was building the reactor, of course, had to learn about the fabrication possibilities, and, believe it or not, they all meshed together and we expanded our operations at Albany to the extent that we made the zirconium sponge free of hafnium, and we melted that. That was another very difficult problem, to make an ingot from the sponge, but we solved that, and I think that the way we are milling zirconium sponge to ingot, has been generally applied to titanium, what we call the consummable arc melting technique, using a copper crucible that is water cooled. Both titanium and zirconium at the melting point will react with any known substance, except helium and argon, so that there is no refractory that will take it. We solved it by simply cooling the container with water, making it out of copper because it had a high thermal conduction and putting an arc on it and just putting up what looked like a pancake. As a result of our work Carborundum Metals Co., a division of Carborundum Corp., recently, during the past few months, has gone into the production of zirconium. Other companies have taken up the melting techniques. We are still operating our zirconium sponge plant at capacity, which is some 300,000 pounds a year. Incidentally, we made our millionth pound of zirconium on August the 20th, I believe.

If zirconium had been produced in the same volume using the only known process at the time we built our pilot plant, the cost of the metal would have been at least $50 million more than has been spent by the Bureau of Mines in producing the metal. And in making the metal we think that we have established a new raw material which inevitably will strengthen our industrial potential. Of course, we expect to get out of the business, as soon as private industry can supply the demands of the Atomic Energy Commission for this particular metal. We would like to, from our point of view, find more industrial applications

for zirconium. Unfortunately, titanium snows us under to some degree because of its remarkable properties, but zirconium is more corrosion resistant than titanium at higher concentrations of acid and alkalis. For example, as we think of corrosion in terms of sea water, titanium will last for a thousand years, as far as we know, so you can't improve on that, but there are certain applications for zirconium.

Senator MALONE. Certain acids which will attack titanium that won't attack zirconium?

Mr. SHELTON. That is right.

Senator MALONE. What about the cost possibility?

Mr. SHELTON. We think zirconium could be made at a price equivalent, within the same order of magnitude as titanium. The only thing that would increase the cost of zirconium with respect to titanium is that it will never be made on the volume production that titanium is. As you make a metal in large volume, your cost goes down.

Senator MALONE. What about the raw materials?

Mr. SHELTON. The raw material is zircon sands, and it is quite available. We speak of these three sisters, hafnium, zirconium and titanium. There is probably a hundred times as much titanium as there is zirconium; there is probably 50 times as much zirconium as there is hafnium, but even at that there is probably more hafnium in the earth's crust than there is mercury and silver. Am I stretching myself, Oliver?

Mr. RALSTON. That is about right.

Senator MALONE. They do say that the titanium components are about the fifth or sixth most plentiful substance in the earth's surface. Is that true?

Mr. SHELTON. I think so, yes.

Senator MALONE. This has opened up an entirely new field, and that, of course, is the value of this to the United States of America. Go right ahead.

Mr. SHELTON. I might touch just a minute on hafnium. Hafnium, of course, has opposite nucleonic properties from zirconium, so it has become of interest again to the Atomic Energy Commission. Hafnium, zirconium and titanium all have a future, I believe, in the carbide business. You know we have been making tungsten from carbides and we will undoubtedly continue to make them, but as the carbide industry expands I feel that all three of these metals will enter into it. They have been used, titanium carbide has been used in the past, but they have started, since the titanium wasn't available they have started with titanium oxide and reduced that in the presence of carbon to make impure carbide that still carried maybe 4 percent oxygen. Here we have the pure metal to start with, so we can make the pure carbide, and the properties I believe will be quite superior to the previous determinations along that line.

I think that completes my survey of what we are doing in Albany and in the Northwest.

Senator MALONE. Well, Mr. Shelton, I can't tell you how I appreciate your coming down here. I hope that you will communicate with the subcommittee at any time that you think you have any other ideas that would lead to improving the field that we are working in.

Mr. SHELTON. Thank you very much.

Senator MALONE. Thank you very much.

And now we will recess the committee to 2:30. There are certain luncheons that some of us would like to attend, and we will be back at 2:30. Thank you.

(Whereupon, at 12:10 p. m., a recess was taken until 2:30 p. m.)

AFTERNOON SESSION

Senator MALONE. The committee will be in order.

Mr. Henry Doerner; will you come forward, Mr. Doerner?

Mr. Doerner, if you will identify yourself for the purposes of the record, and proceed in your own way. Your field, the committee understands, is in chromium. Just give us any information that you think would be helpful to the committee.

STATEMENT OF HENRY A. DOERNER, CONSULTING METALLURGIST, SAN FRANCISCO, CALIF.

Mr. DOERNER. My name is Henry Doerner, and I am a consulting metallurgist in this city.

Senator MALONE. In this city, San Francisco?

Mr. DOERNER. In this city, yes, and for quite a number of years I have made a special study of the metallurgy of chromium, particularly the problem of utilizing the low-grade domestic ores. This study has been based upon quite extensive fundamental and technological research carried out previously while employed by the United States Bureau of Mines.

PROBLEM OF UTILIZING DOMESTIC CHROME ORES

I have read the report of this committee and given special study to the parts of that report dealing with chromium, and I want to say that I am very favorably impressed with the factual information that you presented there and the conclusions that you have arrived at. Your committee hearings have shown the urgent need for a domestic chrome industry that will at least reduce our present dependence on foreign sources of cromite ore. This ore is used to make ferrochromium, chromium chemicals, and chrome refractories, and specifications for the ore depend upon the use. There are large domestic chromite deposits that could supply the chemical and refractory industries at a higher delivered cost than the price of imported ore. Of the three major uses, production of ferrochromium is of highest strategic importance and the metallurgical industry has established the most rigorous specifications for that use.

Ores that meet metallurgical specifications are relatively scarce, and known domestic deposits of such ore are too few and small to supply more than a small part of our essential requirements, even when production is stimulated by General Services Administration guaranty of a price that is 2½ times the market price of imported ore. We must therefore produce ferrochromium from low-grade ores that have not been regarded as acceptable for that purpose.

My studies have shown that low-grade chromite can be upgraded to meet metallurgical specifications only by chemical treatment at excessive cost. They also show that such ores can be smelted directly to produce ferrochromium containing more iron than standard grades

but entirely acceptable by the steel industry. I would like to introduce an article in the August 1952 issue of Engineering and Mining Journal describing tests carried out by Republic Steel Co. that demonstrates the satisfactory commercial use of ferrochromium produced by smelting low-grade chromite ore.

Senator MALONE. The article will be accepted as exhibit No. 1 as part of your testimony. At this point I would like to ask you a question Mr. Doerner: Do the specifications as they are written and customarily used work to the disadvantage of the domestic product?

Mr. DOERNER. Yes. Ores which are normally used for metallurgical purposes come from high-grade deposits, which are generally relatively small and cannot be mined by large-scale low-cost mining methods. In other words, they are mined by selective mining and then hand sorting, and those methods are not adapted to this country, where labor costs are high. In foreign countries those same types of deposits can be operated, because of the very low labor costs. It happens that those types of deposits give a sorted product which contains 48 percent Cr_2O_3 with a 3 to 1 chrome-iron ratio, whereas the ores which are concentrated from the low grade, disseminated deposits have a lower chromium content and a lower chrome-iron ratio, both of which are penalized.

Senator MALONE. And that applies more to domestic than foreign ores?

Mr. DOERNER. The penalties apply to domestic and to foreign ores.

Senator MALONE. Except for the price of doing the work?

Mr. DOERNER. Yes; the type of deposit which yields these high-grade products are generally those which cannot be mined cheaply with high-cost labor.

Senator MALONE. So then the advantage lies with the foreign deposits, they have lower-cost labor to handle the situation?

Mr. DOERNER. Yes; that is the main consideration.

Senator MALONE. Mr. Doerner, you have had a long experience in this business. What is the availability of chromite in this country, that is to say, the amount that could be produced over a long period of years to contribute to the annual utilization of this product; could it be materially increased over what it is now if there were proper principles laid down, or is there actually a scarcity, as some would have us believe?

Mr. DOERNER. There are very large deposits of low-grade chromite, but the value of these have been discounted because they cannot be concentrated to a product regarded as acceptable for metallurgical use. There is no way to establish the amount of high-grade ore that could be developed by intensive effort, but the consensus of mining engineers who have studied the problem is that we could not produce enough high-grade ore to obtain more than a small part of the ferrochromium now being used.

Senator MALONE. That is at a certain price. What I am trying to get at is the amount of ore that would be available.

Mr. DOERNER. At any price. General Services Administration is paying two and one-half times the market price, but the production of metallurgical grade ore is a very small fraction of domestic consumption. What I am trying to bring out is the fact that we can

produce a very large amount of low-grade chromite and that such ore can be used to produce ferrochromium directly at much less cost than is possible from high-grade domestic ores.

Senator MALONE. What the committee has been looking for, searching for, is some kind of a domestic policy or principle that will gain maximum economic production. When I say economic production, I would define it this way: with a duty or a tariff on the material, whether it is textiles or crockery or clothespins, that roughly, on a flexible basis determined by the Tariff Commission, would make up the difference between the wages and taxes and other costs of doing business here and in a chief competitive country. Now, just what that price would be, or just what that tariff or duty would be, I am unable to say at the moment, but the Tariff Commission knows how to fix it, and if that were the principle laid down by Congress it would overcome this problem that you have just described; that is, that the same kind of ore can be sent in cheaper than you can produce it here. It would make up that difference in the duty, and on that basis of principle according to law, where it would require hearings and witnesses and a special act of Congress to change, perhaps there would be more private money invested in business, wouldn't you think?

Mr. DOERNER. I was coming to that point, and I would like to elaborate on it, if I could.

Senator MALONE. You go right ahead. I am very much interested in your testimony.

Mr. RALSTON. Just a moment. A suggestion has been made that we have already received some testimony in regard to the price of the chrome content in ore, but the content of chromium in ferrochromium has never been thoroughly covered. Now, I hope that you will go right ahead in your own way and give us the story on both sides of the fence there.

Mr. DOERNER. I will be glad to do so. Many research groups have been trying to find some practical way to upgrade these ores, to change the chrome-iron ratio. As a matter of fact, it can only be done by a chemical operation, because the chromium and the iron and the aluminum and the magnesia are chemically combined in a single crystal, and you cannot change that ratio, you cannot change the grade of a chromite concentrate except by a chemical operation. Technically, there is no problem at all, it is very simple to take a chromite ore and upgrade it to equal or even exceed the normal standard specifications, but it is a matter of cost. I think roughly the cost of upgrading would be about the difference between the General Services Administration prices for low-grade and high-grade ores.

Senator MALONE. By upgrading you mean sorting?

Mr. DOERNER. No, I mean chemical treatment. It is not possible to convert such ores to metallurgical grade except by a chemical treatment which is expensive. It does not appeal to me as a economic operation, so I have recommended that such ores be smelted directly to make ferrochromium.

Now in regard to Mr. Ralston's comment on the chromium content of ferrochromium, it is a fact that ferrochromium derived from high-grade ore contains 65 to 70 percent Cr whereas ferrochromium produced by milling and smelting a typical low-grade ore will contain only 55 percent Cr. The only difference is the iron content and since

the ferrochromium is used only to produce chromium steels, the high iron content of the ferrochromium derived from low-grade ore should have a plus rather than a negative value. The price of ferrochrome is based only upon the chromium content.

Senator MALONE. I am interested in your testimony particularly since you come to the point where you can, without difficulty, smelt and utilize this low-grade ore. But what principle laid down by Congress would bring the prospector and the miner and the investor back into the business on a sound basis?

Mr. DOERNER. There is no doubt that a tariff on chromite equal to the difference between the labor and transportation costs on domestic and imported ore would make possible a self-sustaining domestic-chrome production.

Senator MALONE. Well, would the situation as it now exists, except for the transfer of the responsibility to fix these tariffs from the Congress to the State Department—if it just reverted to the Tariff Commission to be fixed on that differential of cost of production, due to these factors that I have already mentioned, and adjusted continually by the Tariff Commission on that basis, would that put you in business?

Mr. DOERNER. Indeed, an adequate tariff will undoubtedly stimulate domestic production of chromite and it may be the only satisfactory long-range policy. However, there has been no tariff on chromite since 1894 and during the 40 years preceding the Trade Agreements Act of 1934 no Congress levied any tariff on chromite. We have a strong ferroalloy industry favored by a tariff on ferrochromium and by duty-free imports of chromite. Tariff protection for chromite is certainly as necessary as the tariff on ferrochromium.

As a temporary, emergency measure to establish the nucleus of a domestic chrome industry that can produce ferrochromium at minimum cost, I recommend that the Government have ferrochromium produced from domestic chromite ores for stockpiling only. The total cost to the Government should not exceed the market value of the ferrochromium if shipping charges are not included.

The stockpile of ferrochromium will have infinitely more value in an emergency than our present stockpile of chrome ore. At a cost equal to or less than the market price, the ferrochromium will be a bargain compared to the present purchase of high-grade ore at two and one-half times the market price.

I would like to submit a prepared statement that includes quantitative data and more complete information to support the following conclusions.

1. To protect our national welfare and security we must produce chromite from domestic deposits to supply at least part of our requirements and especially that used to make ferrochromium.

2. The potential supply of metallurgical-grade ore from known domestic deposits appears to be too small for a substantial contribution to our requirements.

3. We do have very large deposits of disseminated chromite that can be mined and milled at relatively low costs. Only a long-range program to develop these low-grade ores has a reasonable chance to increase domestic output materially.

4. Chromite concentrates derived from such low-grade deposits can be upgraded to meet standard metallurgical specifications only by chemical methods that are too costly for economic use.

5. Such concentrates can be smelted directly to produce ferrochromium at much less total cost than by smelting the more expensive high-grade chromite or upgraded concentrates derived from domestic deposits.

6. There appears to be no technical method by which chromite can be produced from domestic deposits at delivered costs below the price of imported chromite of the same grade. Domestic production of chromite cannot compete with imported ore until we have a tariff on the latter that is equal to the difference in labor and transportation costs. This difference is less on low-grade than on high-grade ores.

7. Until an adequate tariff protection is achieved our security can be protected most effectively and economically by a Government program to have ferrochromium produced from domestic chromite. Such a program will establish continuing operations based upon domestic chromite produced at minimum costs, and the operations can be expanded rapidly to meet an emergency. They will serve also as a sound basis for a study of our need for tariff protection.

(The statement referred to follows:)

STATEMENT BY HENRY A. DOERNER, CONSULTING METALLURGIST, SAN FRANCISCO

UTILIZATION OF DOMESTIC CHROMITE

This statement is intended to show the necessity and feasibility of producing ferrochrome from domestic ores that do not meet standard metallurgical specifications. From statements by Fay I. Bristol and Durand A. Hall on pages 221-236 of part 10, Senate Resolution 143 hearings, the following conclusions can be established:

(1) Production of ferrochrome from domestic ores is so important to our national security that General Services Administration is now paying two and one-half times the market price for chrome ore than meets standard metallurgical specifications.

(2) The cost of producing such high-grade chromite in the United States is approximately double the market price.

(3) The General Services Administration program (open market) for stockpiling domestic chromite does not assure a producer time enough to amortize the expense required to develop an ore body and to install equipment for large-scale operations, especially if a concentrating mill is needed.

(4) The potential supply of metallurgical-grade ore is so small that it can have a slight effect on a defense or war program. Only a long-range program to encourage development and exploitation of low-grade ores has a reasonable chance to increase the domestic output materially.

(5) Aside from the negotiated contract to produce 900,000 tons of chromite concentrate from the Mouat mine in Montana, Government efforts have failed to accomplish a substantial production of chromite.

The following observations are offered as additional information to supplement the previous hearings:

Chromite is used to make ferrochromium, chromium chemicals, and refractories. Each industry—metallurgical, chemical, and refractory—has established specifications for the grades of ore best suited to its needs, but the metallurgical specifications are the most rigorous and difficult to meet. There are numerous large domestic deposits of chromite that could supply the chemical and refractory industries at a somewhat higher cost than the price of imported ore. But ores that meet metallurgical specifications are scarce and known domestic deposits of such ore are too few and small to supply more than a small part of our essential needs, even at prohibitive prices. Therefore, to decrease our dependence on foreign chromite, we must produce ferrochromium from low-grade ores that have not been regarded as acceptable for that purpose.

Chromite is found in three general types of deposits:

(*a*) Small, segregated bodies of nearly pure mineral from which all metallurgical lump ores are derived.

(*b*) Lenses or bands in which fine-grained chromite is intimately disseminated in an igneous complex.

(*c*) Placer sands derived from primary deposits (*a*) or (*b*).

Chromite disseminated in deposits (*b*) or (*c*) can be utilized only by a milling and concentrating operation to separate fine grains of chromite from the gangue constituents.

Selective mining and hand sorting methods applied to the small segregations of chromite involve high labor costs that prevent competition with chrome ores imported from countries having low living standards. Also, such deposits in this country have not yielded substantial amounts of high-grade ore, even at inflated prices. Ore from our large deposits of low-grade chromite can be mined and milled by efficient, large-scale operations at about the same cost per unit of Cr_2O_3 as the price of imported, high-grade ore.

Unfortunately, the chromite minerals in our large, disseminated deposits are generally low grade and concentrates obtained by milling such ores have not been considered acceptable to the ferroalloy industry. This situation is caused by the unusual nature of the mineral chromite, the implications of which are important but often not fully appreciated.

Chromite is the only source of chromium. It is defined as $FeOxCr_2O_3$ a chemical union of iron and chromium oxides, but it also contains variable amounts of magnesia (MgO) and alumina (Al_2O_3). Unlike the gangue in an ore, these "impurities" are chemically combined in the "pure" mineral and they cannot be separated by any mechanical (i. e., ore dressing) treatment. Thus the composition of "pure" chromite varies over a wide range and its Cr_2O_3 content may be less than 40 percent and seldom exceeds 60 percent, although the theoretical maximum is 68 percent.

When a report (by the USBM in pt. 1, p. 76, hearings, S. Res. 143) states that "Montana's extensive (chrome) deposits are low-grade and not acceptable in general commercial practice," it means that the "pure" mineral is low grade and therefore the best concentrate that can be obtained by milling falls short of established specifications for metallurgical use. It does not mean that the ore has a low chromite content, since the latter is nearly 50 percent as mined. This distinction is very important and a basic factor in the utilization of chromite ores.

Specifications for metallurgical chromite call for lump ore containing not less than 48 percent Cr_2O_3 and a 3-to-1 ratio of chromium to iron. This arbitrary standard is based upon the best available imported ores, i. e., those that can be smelted to produce ferrochrome at less cost per unit of chromium than is possible when lower grade ore is smelted. When the chrome-iron ratio in the ore is 3 to 1, the ferrochromium will contain 65-to-70 percent chromium metal.

Chromite concentrate produced from our largest "low-grade" deposits has a Cr-Fe ratio of 1.5 to 1 and ferrochromium obtained by smelting such concentrate contains approximately 55 percent chromium metal. The only difference between this alloy and the standard grade is a higher iron content. Since ferrochromium is priced upon the chromium metal content of the alloy and is used only to produce chromium steels, the high iron content of an alloy should have a plus rather than a negative value. Yet the power of custom is so strong that an alloy containing only 5 percent chromium is still regarded with suspicion 2 years after its satisfactory use was demonstrated by Republic Steel Co. in cooperation with the United States Bureau of Mines. Details of these tests are reported in my article in Engineering and Mining Journal of August 1952.

Suspicion regarding the utility of 55 percent ferrochrome is seldom found in the steel industry that consumes the ferrochrome, but it is still reflected in the scale of premiums and penalties established by General Services Administration in its chromite purchasing schedule. The base price in this schedule is $115 per long ton of lump ore containing 48 percent Cr_2O_3 and a Cr-Fe ratio of 3 to 1 or higher. There is a premium or penalty of $3 per ton for each percent of Cr_2O_3 above or below 48. A penalty of $3 per ton is imposed for each 0.1 point below the standard Cr-Fe ratio of 3 to 1. This penalty is excessive. A penalty of $5 per ton is applied to fine-grained chromite such as a mill concentrate.

Prices are thus based in part upon the Cr_2O_3 content of an ore, but the price of ferrochrome derived from the ore is based upon the chromium metal (Cr) content which is 68.5 percent of the Cr_2O_3. Approximate values listed in the last column of table 1 were computed as follows: One long ton of 48 percent ore at $110 contains 1,0775 pounds of Cr_2O_3 or 735 pounds of chromium at 15.0 cents a pound. General Services Administration accepts a minimum of 42 percent Cr_2O_3 and a Cr-Fe ratio of 2.0 to 1 on its open-market schedule. Prices below those limits were computed by extrapolation to 38 percent Cr_2O_3 and a 1.5-to-1 Cr-Fe ratio, as a comparison with the price paid for Montana concentrate of

that grade. The significance of the General Services Administration schedule is more apparent when these computed values are compared.

TABLE 1.—*General Services Administration price schedules for chromite concentrates*

Grade Cr_2O_3	Ratio Cr-Fe	Price per long ton	Price per pound of Cr contained
GSA price schedule:			*Cents*
48 percent	3.0	$110	15.0
46 percent	3.0	104	14.8
44 percent	3.0	98	14.5
42 percent	3.0	92	14.3
48 percent	2.5	95	12.9
46 percent	2.5	89	12.6
44 percent	2.5	83	12.3
42 percent	2.5	77	12.0
48 percent	2.0	80	10.9
46 percent	2.0	74	10.5
44 percent	2.0	68	10.1
42 percent	2.0	62	9.6
Extrapolated GSA schedule:			
48 percent	1.5	65	8.9
46 percent	1.5	59	8.4
44 percent	1.5	53	7.9
42 percent	1.5	47	7.3
40 percent	1.5	41	6.7
38 percent	1.5	35	6.0
American Chrome contract:			
38 percent	1.5	39	6.7
Engineering and Mining Journal, October 1954:			
48 percent	3.0	44–49	6.0–6.3
44 percent	(1)	21–22	3.1–3.7
High-carbon ferrochrome			24¾
Low-carbon ferrochrome			34½

[1] No ratio specified, normally less than 2.0.

Table 1 reveals a reasonable reduction from 15 to 14.3 cents per pound of chromium when the grade drops from the standard 48 percent to the minimum 42 percent Cr_2O_3. If the Cr-Fe ration drops to 2 to 1, the price of 42-percent ore is only 9.6 cents per pound of chromium, a penalty of 37 percent. Extrapolation to 38 percent Cr_2O_3 and a Cr-Fe ratio of 1.5 to 1, brings the price to only 6.0 cents a pound of chromium, a 60 percent penalty that cannot be justified on an economic basis. The contract price now being paid by General Services Administration for Montana concentrate is $34.75 per short ton of minimum 38 percent Cr_2O_3 grade, which is equivalent to 6.7 cents a pound of chromium.

As shown in the last column of table 1, prices for chromite indicate that the penalties in the General Services Administration schedule are based chiefly on the assumption that a chrome iron ratio of 3 to 1 is essential for satisfactory production of ferrochromium. The ratio in a low grade chromite can be improved to the standard grade only by expensive chemical methods, and the estimated cost in specific instances is approximately equal to the penalties imposed on the low grade ore.

As was demonstrated in the Engineering and Mining Journal article referred to previously, ferrochromium obtained by smelting low grade ores is entirely satisfactory and can be produced at much less cost from low grade concentrates valued at 6.7 cents per pound of chromium than from upgraded or high grade ore valued at 15.7 cents per pound of chromium contained.

The cost of smelting low grade concentrates such as are produced in Montana may exceed the cost of smelting high grade ore by 2 or 3 cents per pound of chromium, depending upon the cost of powerplant capacity and other variables. Montana (also other Western States) is handicapped by a freight differential of about 2 cents per pound of chromium, whether the product is shipped to an eastern industrial city in the form of a concentrate or as ferrochromium. Chromite concentrate can be produced in Montana at about the same cost (per pound of chromium) that is paid for imported metallurgical ore. But higher smelting and shipping costs add 4 to 5 cents to the delivered cost of ferrochromium derived from Montana ores, and an equivalent tariff will be needed on imported chromite before Montana chromite can compete with imports.

Our domestic ferrochromium industry is favored by a tariff on ferrochromium produced from duty-free imports of chromite. It has no incentive to use domestic

ores that must be sold at higher prices than foreign ores produced with low cost labor. This situation has prevented the development of an integrated chrome industry that could be based upon our plentiful, but low grade domestic ores. I believe our Government should adopt a policy that will make such an industry possible. A tariff representing the difference in cost of mining chromite here and in foreign countries would accomplish that result.

As an alternative to stockpiling chromite ore, the security of our country will be served more effectively and efficiently by stockpiling ferrochromium produced from our abundant low grade ores. Such a program will store labor and power as well as chrome. Ferrochromium can be stockpiled in less space and can be stored and transported without the loss that inevitably occurs when fine-grained concentrate is moved or exposed to wind and rain.

Ferrochromium can be produced from Montana chromite for less than the market price by smelting the concentrate and stockpiling ferrochromium at the mill site. Such a stockpile will be an outstanding bargain compared to the current purchase of high grade chromite at 2½ times its market value.

To smelt the 900,000 tons of concentrate that will be produced at Mouat will require about 1,620 million kilowatt-hours and the product will supply wartime requirements for a year or more. If war starts with atomic attacks, destruction of major power plants is likely and any available power will be needed urgently for other vital purposes. Under such a situation the ferrochrome will be priceless, but the crude concentrate might be almost useless.

As a temporary expedient that will relieve an emergency situation in regards to chromite, I recommend that our Government have ferrochromium produced from domestic chromite, and that the product be stockpiled. Such a program applied to low grade domestic chromite will provide an opportunity to develop a permanent industry based upon large deposits of chromite in this country, an industry that can be expanded in an emergency and assure a continuous supply of this strategic material. Ferrochromium can be produced from domestic ore at minimum cost by an efficient integration of mining, milling, and smelting under one management.

As stated on page 39 of the subcommittee report No. 1627, "It is imperative that we take action to establish incentives for our domestic, producing industries which must constitute our first line of defense. A going-concern industry is in itself a most dependable stockpile." These valid statements can be implemented most effectively in regard to chromite, by the following governmental actions:

1. Impose a tariff on imported chromite of 4 to 5 cents a pound of contained chromium.

2. A program to smelt and stockpile ferrochrome derived from large, developed reserves of chromite ore that can be mined and concentrated at a demonstrated low cost.

Senator MALONE. Mr. William Aitkenhead, Washington State College—Mr. Aitkenhead—is it Mr. Aitkenhead or Doctor?

Dr. AITKENHEAD. If you please, as you wish.

Senator MALONE. If it is Doctor, we will give you your full rank.

Synthetic mica: We have heard some testimony on synthetic mica and it has been very interesting, and we would be glad to get your ideas, and on new manganese discoveries, so if you, Doctor, will identify yourself for the subcommittee, and proceed.

STATEMENT OF DR. W. C. AITKENHEAD, MINING EXPERIMENT STATION, WASHINGTON STATE COLLEGE, PULLMAN, WASH.

Dr. AITKENHEAD. I am William C. Aitkenhead, director of the mining experiment station, Washington State College, Pullman. I will describe very briefly what I have to say, because we have no world-shaking discoveries to report or anything like that.

PROGRESS IN MAKING SYNTHETIC MICA

With regard to synthetic mica, I had the privilege of working from 1948 to 1950, summer, two and a half years, at Colorado School of

Mines, under a contract with the Army Signal Corps, and we got along toward what I thought approaching success in making synthetic mica that would give splittings of commercial value. We were not able to reach our goal, but I think the goal is attainable, and I would like to mention if the need for mica splittings ever becomes urgent, I believe that continuing the work that we started there at Colorado School of Mines would be well worthwhile, because I think that we had good indication of success, and with some more funds and some more time I believe it could have been accomplished.

I have some samples of synthetic mica if you would like to look at them.

Senator MALONE. We would be interested in the samples, Doctor.

Dr. AITKENHEAD. Yes.

Senator MALONE. But are you familiar with the progress that has been made in synthetic mica by the Mica-Lex Co., headquarters in New York? We had their testimony before the committee, and very positive testimony, that they could replace the natural product, and in some cases it may even be better than the natural product.

Dr. AITKENHEAD. Well, their product is a built-up product.

Senator MALONE. Built-up product made out of the——

Dr. AITKENHEAD (interposing). Splittings imbedded in plastic, I believe is the process, is it not?

Mr. HOLDERER. Yes.

Dr. AITKENHEAD. Well, I am familiar with that. Now, I cannot say that their product will answer all specifications and all requirements for mica. Perhaps Mr. Ralston could tell me that. I have not been able to keep up to date since we got out of the mica business.

Senator MALONE. But the synthetic mica from the progress of your own studies could at least replace a substantial part of the product that is used in industry?

Dr. AITKENHEAD. Yes.

Senator MALONE. And the earmarks are that it might be entirely successful?

Dr. AITKENHEAD. I think that our work pointed to success in making true mica that would split, just like natural mica, and with improvements in the process we could have got the splittings big enough. I understand that for much of the—many of the applications for mica where they are using it in these very small condensers for electronic work that splittings, oh, an inch square in many cases, have been big enough.

Senator MALONE. Now, here we have comments on page 105 of this Report No. 1627.

Dr. AITKENHEAD. Yes, I have read that.

Senator MALONE (reading):

> In recent years, methods have been developed for producing a mica insulating material from scrap mica. The new product, reconstituted mica, possesses many mechanical and electrical properties superior to those of the conventional built-up mica product, which is made from imported splittings. It is anticipated that the new product will replace almost all uses of splittings and possibly some strategic electronic uses, in turn alleviating United States dependence on foreign sources. The Bureau of Mines Electrotechnical Laboratory has developed methods for producing synthetic flake mica as a raw material for industrial uses, such as glass-bonded mica ceramics, hot-pressed ceramic dielectrics, and as a bonding agent in abrasive wheels.

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Now, as I remember this company, their statements were considerably more positive.

Mr. ADLERMAN. That was in the Congressional Record at a later date.

Senator MALONE. You don't have it?

Mr. ADLERMAN. No.

Senator MALONE. I just thought you might be familiar with that.

Dr. AITKENHEAD. Yes, I am familiar with that.

Senator MALONE. And we do not know, at least I do not know as chairman of the subcommittee, that their statements are entirely correct.

Dr. AITKENHEAD. I do believe there are certain uses—you mentioned strategic mica—where we still need the mica, that is, the real mica splittings, in small condensers for electronic equipment, and I believe that such splittings could be made synthetically. As a matter of fact, I have made splittings as big as a dollar, a few of them. I can make splittings as big as my thumbnail by the ton. There are certain techniques that must be developed to bring the process to success.

Senator MALONE. Now, the process, if perfected, would be within the economic range?

Dr. AITKENHEAD. Yes. When we were working on it, the raw materials cost about 7 cents a pound, so the cost of the raw materials is negligible. The furnace—the furnacing, of course, would produce a small yield of at best, I should say, a small yield of usable mica, but suppose we got 5 percent of our charge coming out as usable mica, it is still cheap compared to the price of high-grade mica that you pay India.

Senator MALONE. Yes, and the greatest value to it, of course, would be the availability of it in wartime.

Dr. AITKENHEAD. Yes.

Senator MALONE. Well now, as with other witnesses, your manuscript will be returned to you, and if you can supplement it in any way and give us references, it would be very helpful.

Now, you did have some information on manganese?

NEW DEVELOPMENTS IN MANGANESE

Dr. AITKENHEAD. Yes. About 6 weeks ago, a member of the Spokane Indian Tribe came to my office saying that he had discovered a uranium deposit. The Spokane Indian Reservation is an area which extends within 30 miles of Spokane, and a small area in the west there. Well, we sent one of our geologists, Mr. Crosby, up to have a look at it, and he not only looked over the uranium deposit, but the Indian said, "Here is something else. What is this we have? It has been here for a long time. We have had it assayed for gold and silver and it doesn't contain any gold or silver. What is it?" Well, it was some very nice showings of manganese ore, and I called the attention of our State geolgist to the deposit.

Senator MALONE. Who is your State geologist now?

Dr. AITKENHEAD. Mr. Sheldon Glover; and he sent one of his men to have a look at it, and his report, that is, superficial examination report, was very optimistic. There is an area there of about 6 miles in diameter where in 6 places this ore outcrops, and it is not a high-

grade ore—we brought back about 1,500 pounds and assayed it and got 6.4 percent, but we determined that it concentrates very easily, it is easy to grind and responds to flotation very nicely.

Now, we can't say anything about the quantities there, but it looks as if it is worth investigating.

Now, the Bureau of Mines in Spokane knows about it, and they have recommended to their headquarters that some drilling be done. However, they were not optimistic because they said, well, the Bureau of Mines is hard up now. We don't know whether we can afford it, but I think that it is something that is well worth watching; and although we can't say that there are large quantities there, it looks as if there may be.

Senator MALONE. Well, this manganese situation is a bit in the same class as tungsten, chromite.

Off the record.

(Discussion off the record.)

Senator MALONE. Four or five metals were included in a bill, paying a special guaranty, a special price under contract. Now, my bill extended it for 2 years, to 1958, I believe, for manganese. Naturally, a new deposit of manganese takes time to prospect, time to build a mill and all, and time would be up. My hope was that before the time was up we would have a principle established by Congress, something on the basis of fair and reasonable competition, with a duty or tariff established by the Tariff Commission, which would be a very simple thing if we would just let this free-trade thing run out and die, just don't pass anything on June 12, 1955, and I really believe we will. I am only one Member of the Senate, however. Private money, prospectors, and explorers would be back in the hills looking for this stuff, knowing that even if it took 10 years to develop it, you would still have paying property; have you given any thought to the policies or principles that might be established by Congress that would facilitate or promote the discovery, exploration, and discovery of new deposits of these minerals?

Dr. AITKENHEAD. Manganese, of course, is in a rather special category. This ore, as I say, is low grade. It is 6.4 percent manganese, and it will require concentration, and I doubt very much in an open market that it could ever compete with imported ores.

Senator MALONE. That is what I am talking about. You are talking about $2 wages, 50 cents a day wages, and so on, but this is what interests me, are we so far away from that, from the dog that bit us, that we don't even recognize what it was?

Dr. AITKENHEAD. Well, I don't believe we are.

Senator MALONE. Well, what is it then?

Dr. AITKENHEAD. Well, it is the fact that we cannot employ labor for 50 cents a day to sort out this ore and put it on the market.

Senator MALONE. Do you know where we lost out, where we strayed from the trail, when we had a tariff or a duty that made up the difference in the labor costs here and abroad; where was that, do you remember?

Dr. AITKENHEAD. Well, I should say it was somewhere back in the teens, around the World War I era.

Senator MALONE. Well, that wasn't the time. We may have gotten off the track a little, but we didn't debark from it, from the principle, until the 1934 Trade Agreements Act. That is when we departed

from the principles. Since that time you have dealt with Bureau officials, and no principle laid down at all. How old are you?

Dr. AITKENHEAD. Oh, I am old enough to have seven grandchildren. I am 57.

Senator MALONE. Well, you are old enough to remember 1934; aren't you?

Dr. AITKENHEAD. Yes.

Senator MALONE. Do you remember that act?

Dr. AITKENHEAD. Yes.

Senator MALONE. Do you realize what it means?

Dr. AITKENHEAD. Well, I do now. At the time I thought it sounded like a very nice thing.

Senator MALONE. Well, it is a very nice thing to have the American market go into the 50-cent areas and bring in stuff that knocks your brains out here. If you like it, it's good.

Dr. AITKENHEAD. Senator Malone, let me make a comment. I doubt that we can ever hope to be self-supporting in manganese within our own borders. It is just not——

Senator MALONE (interposing). What area are you familiar with besides your own?

Dr. AITKENHEAD. I have read, of course, the Bureau of Mines Report on Manganese and Manganese Exploration. They had manganese in southern Nevada, there is manganese in Maine, the Aroostook region, there is manganese in South Dakota, and I believe some in North Dakota; it is rather widely distributed, but we are not fortunate enough to have large masses.

Senator MALONE. Do you think it is necessary to be self-sufficient?

Dr. AITKENHEAD. No; I don't.

Senator MALONE. It is necessary, according to the military strategists, to be self-sufficient in the Western Hemisphere. Now, you can do that all right, can't you?

Dr. AITKENHEAD. Well, we can.

Senator MALONE. There is probably enough in Brazil to last the country 700 years.

Dr. AITKENHEAD. Well, deposits like this, as I just mentioned——

Senator MALONE (interposing). But what would go to make an economic production here feasible, an economic production, meaning if you had a protection that equaled the difference in the labor and the taxes and various factors, the expense of doing business between here and your chief competitive nation. Now then, you could be in business if you produced 30 percent, 20 percent, or 50 percent, 10 percent, you are in business, aren't you?

Dr. AITKENHEAD. Yes.

Senator MALONE. On a principle.

Dr. AITKENHEAD. Yes.

Senator MALONE. Well, what do you think about that?

Dr. AITKENHEAD. Well, I think it would be a very good thing if we could do it.

Senator MALONE. Well, what do you mean, if you can do it?

Dr. AITKENHEAD. Well, I was going to mention this deposit here.

Senator MALONE. Well, now, let's begin, let's keep on the principle. What do you mean, if you could do it; if you can establish the principle?

Dr. AITKENHEAD. If we can mine an ore that is comparable to the ore that is mined in these foreign countries, then a tariff which would

make up the difference between our cost and their cost would put us in business; but this is not a high-grade ore, and I don't believe—suppose this ore existed in Brazil, I don't think it would be worth looking at, because Brazil has high-grade ores that they can exploit. Such an ore in the United States, it seems to me, is a nest egg for an emergency. It should be developed, prospected to a certain extent.

Senator MALONE. Who is going to pay for it?

Dr. AITKENHEAD. I was wondering about that.

Senator MALONE. The only way you can get into development is to have an incentive of profit, isn't it?

Dr. AITKENHEAD. That is right.

Senator MALONE. Unless you, like everybody else, are looking to the taxpayers to carry the load.

Dr. AITKENHEAD. Well, I think that you understand my point on this particular deposit. It is low grade, and I doubt very much if it would be exploitable in a country that had high-grade manganese.

Senator MALONE. Well, you don't have high-grade manganese in this country.

Dr. AITKENHEAD. That's it.

Senator MALONE. Well then, can you think of any principle that would put the prospectors out looking for manganese in this kind of a situation, and any private money that would go into it; what kind of a principle would you have to have?

Dr. AITKENHEAD. It would have to be a principle that would at least, perhaps not assure, but give a good chance of profit.

Senator MALONE. It's been 20 years since anybody said that.

Dr. AITKENHEAD. Well, that's absolutely right. We still operate on profits. We can't operate unless you make profit.

Senator MALONE. We haven't operated on profit for 20 years, except out of the Treasury. It has cost you $260 billion in 20 years, and we have about a 15 or 20 billion dollar debt.

Dr. AITKENHEAD. Well, speaking of capital, I do know of two sources of capital that are interested in that manganese, but I think they are interested because the Government pays somewhat over twice the market price for manganese.

Senator MALONE. That is my bill that extended it to 1958. What we are trying to look for is something that would keep away from special legislation.

Dr. AITKENHEAD. With that provision of a special price for the producer of domestic manganese, I believe capital can be interested in this deposit. A gentleman yesterday, in the presence of Mr. Ralston, expressed his interest, and I do know that there is a group in the State of Washington that are interested.

Senator MALONE. Well, they want to know who is going to drill it for them, who is going to mine it for them, and who is going to pick up the check at the end of the month; that's what they are worrying about, isn't it?

Dr. AITKENHEAD. That's right.

Senator MALONE. Well, could you start thinking about some kind of a principle we could adopt?

Dr. AITKENHEAD. The only principle I could think of, Senator Malone, is the old-fashioned tariff.

Senator MALONE. What kind of a tariff would you like?

Dr. AITKENHEAD. A tariff that would make up for the difference between our costs and wages and the costs and wages in manganese-

producing countries. Perhaps we would even have to go further than that; if we are going to develop our own low-grade ores we are going to have to have a tariff a little higher than enough to make up for this difference in labor, because we are treating material that is more costly to treat by nature than theirs. Ours takes more effort, more equipment, more machinery to concentrate it.

Senator MALONE. I think you are right.

Now, as a matter of fact, if we didn't extend this 1934 Trade Agreements Act and let it expire at midnight on June 12, 1955, it reverts to the Tariff Commission. However, if we had a trade agreement to lower the tariff on manganese, the President would have to serve notice of cancellation, before the right to set a tariff reverts to the Tariff Commission. Now, if you need further incentive beyond the tariff protection making up the difference in cost of doing business, like your wages and taxes and other incident costs, perhaps then it would be a matter for Congress to consider special legislation, like on sugar for example. There wouldn't be very many things that would be necessary for us to produce here for national security and for our economic structure that the tariff, on the basis of fair and reasonable competition, wouldn't put in business, would there?

Dr. AITKENHEAD. I can't think of any.

Senator MALONE. Then on the few that it was necessary to do additional work beyond that principle, Congress could consider a special bill on a basis of national security, could they not?

Dr. AITKENHEAD. Surely, yes.

Senator MALONE. And I think they would, because we have already shown that you could pass a special bill when it is necessary.

Dr. AITKENHEAD. Yes.

Senator MALONE. But if you are for that principle—you are from Oregon?

Dr. AITKENHEAD. No, I am from the State of Washington.

Senator MALONE. You are from the State of Washington?

Dr. AITKENHEAD. Yes.

Senator MALONE. Well, I would suggest you discuss this with your Senators and Congressmen. They are the only ones that can help you, and if we let this thing expire and you go back to the method of protection up to that point of economic production—I call economic production "protection"—amounting to the difference in the wages, taxes, and other factors of doing business, then, if there is any deposit, or put it the other way around, if we need more exploration in this country to be safe, than that protection affords, then a special act would be in order, would it not?

Dr. AITKENHEAD. Yes.

Senator MALONE. I believe we can get those kinds of special acts.

Now, Doctor, if you would give this some thought; do you have this report?

Dr. AITKENHEAD. Yes, I have a whole briefcase full of those reports. I am taking some back to give to my colleagues.

Senator MALONE. Did you get the hearings of the committee, 10 volumes of public hearings?

Dr. AITKENHEAD. No.

Senator MALONE. Well, they are available at the Government Printing Office, and they are very interesting, because of the type of wit-

nesses we called. We didn't call anyone, purposely at least, that didn't know their business in a particular field that their testimony covered. There are 360 people, producers and engineers and Government engineers and economists, in 58 different hearings, and then we digested this 10 volumes into the 1 summary of recommendations, findings, and supporting data.

I would also appreciate it if in your testimony, when you correct it, you can give us any recommendations of further work the subcommittee should do, realizing that what we want is factual information and suggestions that would go to further stabilize the economy of the country and make for its greater security.

Dr. AITKENHEAD. Would you object to my calling together some of my colleagues and having a meeting, talking it over?

Senator MALONE. That would be very much appreciated.

Dr. AITKENHEAD. I see.

Senator MALONE. And, if you want to, then you could have a section of your testimony that would be just what it purports to be, an agreement, or whatever you call it.

Dr. AITKENHEAD. Yes.

Senator MALONE. And we are very appreciative of your coming here today. We held this meeting for the same reason we held the one in Seattle last year, because of the character and experience of the men that attend these conventions. It gives us an opportunity to secure the advice and counsel of these men without putting them to the expense of coming to Washington, or the subcommittee's expense of going a number of places, so thank you very kindly, and you will receive your transcript.

(The following material was submitted for the record:)

SPRINKLER CORROSION CAN BE STOPPED

By Robert L. Sincock, associate editor, the Washington Farmer

Spots inside a length of aluminum sprinkler irrigation pipe looked to an eastern Washington farmer something like barnacles. Holger Hansen, of upper Crab Creek, squinted through the pipe again. Daylight whirled back from the far end provided a better answer this time. Those marks were crust—and pits—in the aluminum itself.

When Hansen turned away from his field below Stratford that July day in 1950 and reported something had happened to his 1-year-old sprinkler system, he had discovered the first case of corrosion to an aluminum sprinkler system in the Pacific Northwest. Since then, aluminum companies have had corrosion complaints from California, Kansas, New Jersey, Pennsylvania, southern Idaho, and Oregon. But the greatest number have come from Washington.

Farmers, dealers, and manufacturers naturally became alarmed. Aluminum pipe, which might be expected to last 10, 15, or more seasons, was being made useless in some cases in only a year. In extreme cases, pipe was destroyed within 6 months after installation.

The Washington State Institute of Technology, a part of Washington State College, was called in immediately. Since then, a team of investigators headed by Dr. Mark Adams, associate chemist in the division of industrial research, has clarified maor questions about when and where corrosion may strike and what can be done about it. Farmers, dealers, and aluminum makers Alcoa, Kaiser, and Reynolds have worked closely with the college, which today is the only place where research is probing into the actual cause of aluminum-pipe corrosion.

There is no single cause. Instead, seven have been found thus far, and Dr. Adams anticipates that he soon may identify the eighth and most damaging of all. He says pipe can be damaged by a combination of causes when coupled with the right temperature and certain other conditions.

Much work still remains to be done on this newest problem of corrosion, but WSC research workers now are ready to give farmers some definite help.

First, these technologists point out, there's nothing wrong with aluminum sprinkler pipe itself. Aluminum, because of its lightness and strength, and because of its resistance to corrosion by many types of waters, is in general an excellent material for portable sprinkler systems. Instead of pure aluminum, an alloy that offers greater resistance to corrosion actually is used.

Numerically, the known cases of pipe corrosion still might be called few and scattered, but more are being reported each season. The trouble is more general in certain districts than others. One of the worst areas is in the Walla Walla Valley.

More than 90 percent of the trouble has occurred in systems using well water, but not all well water causes corrosion. Equally significant is the fact that 95 percent of the damage is confined to the main lines, with very little in the laterals. Damage occurs to main lines kept under pressure rather continuously.

Dr. Adams says it's probable there are many as yet undiscovered cases of damage because virtually all corrosion takes place inside the pipe. That's why WSC welcomed this first farm-magazine report on the subject. Farmers now can watch for signs of damage, knowing they can stop it.

Sprinkler systems used periodically have not had trouble. Dr. Adams thinks that's the reason why there are no reports of corrosion from western Washington, where supplemental irrigation with sprinklers is both widespread and periodic. But even if draining the system once a week might check corrosion, this still wouldn't be practical for many arid-land, interior farmers, he points out.

There's no problem in wheel-type systems hooked to buried steel main lines because wheel systems must be unhooked to change settings and the aluminum part of the system then drains itself.

Adams and his research associates have worked out a practical solution which farmers having trouble can carry out themselves: "It's simply to paint the inside of the pipe, using certain paints. R. M. Wade & Co., Portland, is the first to offer such commercial treatment on request, at a percentage of the system's cost.

In making painting suggestions, one aluminum manufacturer has notified its irrigation distributors: "There are some types of waters and conditions of service where corrosion will occur. Where unusually severe or rapid corrosion is encountered or is expected, we suggest that a protective coating be applied to the interior of the pipe * * *."

This manufacturer suggests cleaning be started by using a phosphoric-acid type cleaner, following the acidmaker's directions. However, where farmers want to paint the pipe themselves, adequate protection can be given without use of the additional acid-cleaning step. Chemist Adams suggested this method:

First, clean the interior of the pipe, using a rotary wire brush attached to a long rod mounted in the chuck of an electric drill. A centering guide would help. Do this from each end of the pipe for half the pipe's length. A rod about 20 feet long is needed for the 40-foot lateral sections; main-line sections are 30 feet long.

Follow this by wiping throughly with a clean cloth. Don't used compressed air; grease and water particles might be blown into the pipe.

Next comes painting. Two men can do the job. Plug one end, pour in 1 gallon of paint (for a 30-foot pipe), then plug the second end. Lay the pipe flat and roll it. Drain excess paint into a bucket. Use thinner only as recommended by the paintmaker. Thinner may save paint, but not the far more expensive pipe.

Reflection of light through the pipe gives a simple check on completeness of the coating. Perfectly complete coverage is unnecessary if chromate-type paints or Zincilate (made by Industrial Metal Protectives, Inc., Dayton, Ohio) are used. That's because chromates and Zincilate (the latter is a zinc-oxide pigment in a polyvinyl vehicle) are corrosion inhibitors themselves. Other paints are cheaper and also can do a good job simply by sealing off the aluminum walls from the water. They depend, therefore, on completeness of coverage.

At first, the user might think a gallon won't go far, but treatment even with Zincilate, which costs about $15 per gallon in the West, results in a protection cost of about 1 cent per foot per 1-inch diameter if the farmer does the work himself. Thus, treatment of 5-inch pipe costs 5 cents per foot, or about 75 cents per acre for main line or $2 per acre for main line and laterals.

These figures can be compared with replacement costs, which vary with type of layout, but they're probably somewhere around $15 per acre for the main-line pipe alone. That's $15 compared with protection cost of 75 cents or less, depending on paint used.

WSC's division of industrial research does not recommend particular brands of paints. At present, here's the way it rates several it has tested for this particular job:

Zincilate, applied to both corroded and new pipe, still provided excellent protection after two seasons, with no signs of paint deterioration.

Fuller metal etch primers—two of them look good; (1) Fuller's zinc chromate pigmented metal etch primer looks very good. (2) Its gray type looks reasonably good. (3) But its red type, pigmented with iron oxide, "didn't show up as well as zinc chromate primer," Adams said.

Montgomery Ward's aluminum metal and masonry paint looks pretty good. It's readily available and relatively inexpensive.

Carbozite, commonly used for roofing, seems to be doing a good job. It's also quite inexpensive.

Asphalt emulsions are to be avoided. They chip from the pipe and plug sprinkler heads.

Theoretically, there are two interesting future possibilities of inhibiting corrosion by bleeding uniformity into the piped irrigation water either ammonia or phosphate or both. These chemicals are corrosion inhibitors as well as fertilizers, and because they're widely needed as fertilizers, Adams pointed out, it might be possible to equip a sprinkler system with an accurate bleeding system to carry out two purposes.

Another means of checking corrosion, used effectively since WSC's earliest research on the subject, is to place magnesium strips in pipe, but this method is not as practical for farmers to use as painting. Adams explained that the magnesium acts as a sacrificial anode, or electric pole, in setting up a reverse battery. The reverse battery prevents corrosion of aluminum. The magnesium in this case is destroyed, not the aluminum.

When pipe corrodes, an electric current begins flowing between poles in the aluminum and doesn't stop. Gas or a solid is liberated at the poles. This galvanic process is destructive as corrosion, but is used to advantage in electroplating.

When exposed to oxygen in the air, pure aluminum immediately acquires a protective coating of aluminum oxide. Once this coating is disturbed and not replaced, the exposed aluminum can corrode. Most metallic oxides are sparingly soluble in water, says Dr. Adams, but if the concentration of salts in the water fed into an aluminum sprinkler system is high, it tends to set up corrosion.

High content of dissolved heavy metals in the water—copper, lead, nickel, and cobalt—eventually may replace the aluminum oxide coating of the pipe and thus start corrosion. However, heavy metal content of waters investigated during WSC's search has been fairly uniform regardless of source and has been of questionable significance thus far.

Similarly, contact of a dissimilar metal with aluminum is another known cause of corrosion. Examples are iron bolts connecting parts of a sprinkler system, and copper and brass contacting aluminum in the valves. Most systems now are built to avoid contact of dissimilar metals.

Differential factors such as difference in temperature between top of the pipe and the bottom are other causes of corrosion that the WSC men have had to investigate.

And there were other points of checking, such as any variations in the surface of metal, where corrosion would occur if other factors permitted. The common practice of nesting smaller pipes inside larger ones for storage is another cause for some corrosion because the pipe is easily abraded, damaging the oxide coating. Sand abrasion in water is not a serious cause.

During the 4 years of chasing the mysterious pipekiller, only one factor has coordinated with corrosion. This is free dissolved carbon dioxide, a factor which doesn't show up in ordinary water tests and couldn't be detected when water samples were taken to the laboratory because once the water system was opened to draw off a sample the carbon dioxide disappeared. Carbon dioxide finally was found by setting up closed system measurement methods.

Although Adams has not yet determined beyond a reasonable doubt that this is the major cause of corrosion, he is confident now it will be the ultimate cause. To him, evidence points strongly to free dissolved carbon dioxide in the water as the destroyer of the aluminum oxide coating that otherwise would protect the pipe from corrosion.

His report will be real news for chemists.

Electrode Carbon from Washington State Coal

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Introduction

1. Object and Nature of the Problem

In the reduction of aluminum, one of the major components of the manufacturing cost is that of the carbon electrodes. Approximately six-tenths of a pound of electrode carbon is consumed in the production of one pound of aluminum, and carbon electrodes account for 12 - 19 per cent of the net aluminum manufacturing costs.[1] Consequently, development of new practical sources for electrode carbon is of considerable importance.

At present, the production of petroleum coke in the Pacific Northwest is negligible. Petroleum coke consumed as electrodes by the aluminum reduction industry in the state of Washington must be imported. For the Washington aluminum industry alone, approximately $4,000,000 was expended for carbon-electrode constituents in 1949. It has been estimated that by 1960 the cost of these carbon-electrode materials may increase more than five-fold to attain a value of approximately $23,754,000. Slightly more than two-thirds of the total carbon requirements of the combined Northwest industries is consumed as electrodes in aluminum manufacture.

The U. S. Corps of Engineers[2] has estimated the total 1960 Pacific Northwest industrial requirements for carbon as shown in Table I.

Table I

ESTIMATED 1960 CARBON REQUIREMENTS

Industry	Tons/Year	Kind of Carbon
1. Aluminum Reduction	878,200	Calcined Petroleum Coke
	33,500	Coal Coke or Calcined Anthracite
	187,000	Hard and Soft Tar Pitch
2. Magnesium Reduction	20,000	Calcined Petroleum Coke
3. Iron Ore Smelting	26,000	Coal Coke
4. Iron and Steel Castings	40,000	Foundry Coke
5. Ferro Alloys	43,500	Petroleum or Coal Coke
6. Silicon Carbide	14,000	Petroleum or Coal Coke
7. Elemental Phosphorus	280,000	Coal Coke
8. Calcium Carbide	90,000	Coal Coke
9. Carbon Disulfide	5,000	Charcoal
Total Estimated 1960 Requirements	1,617,200	

The approximate total value of these quantities of carbon may be estimated at $32,344,000 (computed on the conservative basis of $20 per ton as the average cost of carbon).

Because the value and quantity of carbon required in the rapidly expanded Northwest aluminum industry represent such a great proportion of the total industrial carbon requirement, it was decided to concentrate on investigating Washington anthracite coal of high, fixed carbon values as a possible source of electrode carbon. Therefore the present study and laboratory investigation of methods of producing ultraclean Washington state coal, suitable for use in the manufacture of carbon electrodes, was initiated as Project Number 232 by the Division of Industrial Research on September 6, 1951. Since study of all available literature in this field revealed a lack of comprehensive information on the subject, it was considered desirable to develop, if possible, a practical industrial process for manufacturing electrode carbon of quality suitable for the aluminum reduction industry.

At first, the most promising anthracite area within the state appeared to be the Glacier Field (See Figure 2) in Whatcom County on State Highway Number 1 directly south of the town of Glacier and about thirty-two miles northeast of Bellingham.[3] This field, discovered

in 1907, was inspected during the period 1910 to 1918 by Edward Dinan, mining engineer, who reported seven known seams and at least three unclassified seams. He reported the coal to be a high-grade anthracite and estimated that forty-five to fifty million tons were available above the 950 foot level.

According, however, to estimates made by the U. S. Geological Survey in 1913 and revised in 1952, the total coal resources within the state were 63,877,000,000 tons of which only 23,000,000 tons, or about 0.04 per cent, were of anthracite quality.[4] These figures show then that if a yeild of 30 per cent of electrode-quality carbon is produced from the anthracite in the state and if the aluminum industry in the Northwest requires annually a total of 911,700 tons, this source could provide the total requirements for a period of seven to fourteen years, or even longer, if the coal resource proves to be greater than fifty million tons. Use of blends of coal carbon with petroleum coke would greatly extend this period.

Other more abundant coals available in the state warrant investigation as sources of electrode carbon. It is of particular note that, during 1951 and 1952, the U. S. Bureau of Mines at Seattle, Washington, investigated the possibilities for producing electrode-grade carbon from bituminous coals.[5] The favorable possibilities for producing low-ash coke from selected bituminous coals from Eastern Kentucky was reported by U. S. Bureau of Mines investigators in 1943.[6] They explored the process in which a mixture of hydrochloric and hydrofluoric acid was utilized to obtain coal of only 0.32-per-cent ash-forming impurities. A full comparison of all qualities of their products with petroleum coke was not published.

2. German Investigations

Prior to 1943, the great expansion of the aluminum industry necessitated by World War II, aroused concern with regard to the available supply of electrode carbon for the aluminum industry.[6] Petroleum coke and pitch coke were in exceedingly short supply in Germany during the war. It was therefore necessary to supplement the electrode-carbon supply with carbon produced from coal.[7] During this emergency, methods previously considered economically unfeasible were adopted. These emergency processes included:

(a) Float-and-sink beneficiation using a suspension of magnetite as heavy density medium followed by froth flotation of the beneficiated coal. The final product represented 26.8 per cent of the raw coal and had an ash content of 0.5 to 0.7 per cent (Koenigin Elizabeth Colliery).[8]

(b) Electrostatic cleaning of dry coal with electrode potentials of 30,000 to 40,000 volts.[9] Coals of 8 to 10-per-cent ash content were processed to values of 1.5 to 4.0-per-cent ash.

(c) Froth flotation followed by acid extraction.[7] Ultraclean coal of 0.9-per-cent ash was produced from feed containing as much as 25-per-cent ash.

(d) Extraction of coal with a solution containing 5-per-cent hydrochloric acid and 5-per-cent hydrofluoric acid. After calcining at 1300° C. (2372° F.), "high conductivity" carbon of 0.6 to 0.7-per-cent ash was produced. This purified coke was estimated to cost about three times that of normal commercial coal coke.

(e) A "wet mechanical process" was investigated,[9] in which a high-speed centrifuge was used to separate the heavy, ash-forming particles.

(f) Ash removal by jig-washing, froth flotation, and caustic extraction. In this procedure, coal of 0.7-per-cent ash was obtainable. For carbon intended for electrode manufacture the quality of first importance was the ash content, after which the electrical resistance was considered of next greatest importance. However, the resistivity of this calcined carbon is believed to have been 0.0232 ohms/in.[3], whereas petroleum coke preferred by the aluminum industry usually has a resistivity value of 0.002 ohms/in.[3] or less.

(g) De-ashing of coal by extraction of coal-oil paste.[10] This process was developed and carried out in a pilot plant. It was found that by kneading the middle or sump oil from the hydrogenation process with pulverized coal dispersed in water, a coal-oil paste was

formed which left much of the high-ash material in the aqueous phase. Coal of 2-per-cent ash content was produced. In some tests the purified coal was treated with acid to further reduce the ash content.

(h) The Pott-Broche Process.[11] In this process, coal was prepared for direct hydrogenation to oil and gasoline and was also followed in the production of electrode carbon. In brief, a paste of ground coal and oil from the hydrogenation process was heated under high pressure, causing disintegration and solution of the coal. It was claimed that the oil from the hydrogenation must have a high proportion of hydrogen to effectively depolymerize the coal.

In general the Germans considered froth flotation as the final step in the physical beneficiation process. Chemical treatment was used to further decrease the ash content beyond that possible with the physical procedures. The effectiveness of the chemical treatment varied greatly with the chemical properties of the coal. The use of these chemical processes, following physical beneficiation, indicates how desperately electrode carbon was needed by the Germans.

3. The Technical Requirements of Electrode Carbon and Electrodes

It appears obvious that, since carbon electrodes consist of nearly pure elemental carbon, the best sources of carbonaceous material for electrodes would be those containing the greatest amount of carbon, i.e., Glacier anthracite coal of more than 80-per-cent fixed carbon. Mineral or ash-forming material remaining in the electrode carbon, will to a great extent be found in the finished electrodes. When used in electrolytic work, the electrical resistivity of the electrode and amount of mineral impurities may be of greatest importance. The electrodes for electrothermic work, however, may contain more mineral impurities since the electrodes are merely refractory conductors of the current and, in general, do not enter into the reactions carried out in the furnace. For instance, the carbon electrodes used in the manufacture of calcium carbide from coal coke and quicklime may have a high ash content because little of the mineral matter from the electrodes will remain in the final product because of low, electrode-carbon consumption as compared with the quantity of coke used in the process. Phosphorous in the coke, however, will appear as a phosphide in the end products, and is considered objectionable. The exceedingly small amount of phosphorous in the Glacier coal would not prevent its use as a source of electrode carbon for this industry.

In electrolytic processes, both electrode purity and resistivity are prime considerations. During electrolysis in the reduction of aluminum, impurities in the electrode will remain in the metal produced.

In approaching the problem of preparing electrode carbon from coal, it is logical that the goal should be the production of carbon which is at least equal, insofar as important properties are concerned, to calcined petroleum coke. Such coke is the standard body material used by the aluminum industry for manufacturing electrodes. The U. S. Bureau of Mines[6] and the U. S. Department of the Interior[2] reported the typical specifications shown in Table II for calcined petroleum coke intended for the aluminum industry.

Table II

TYPICAL SPECIFICATIONS FOR CALCINED PETROLEUM COKE

Requirement	Bureau of Mines	Dept. of the Interior
Moisture, per cent	---	0.50 Max.
Volatiles, per cent	---	0.50 Max.
Ash, per cent	1.0 Max.	0.50 Max.
Fe, per cent	0.06 Max.	0.06 Max.
Si, per cent	0.08 Max.	0.06 Max.
Ca, per cent	*0.12 Max.	*0.12 Max.
Na, per cent	*0.12 Max.	*0.12 Max.
Real Density	2.02 Min.	2.05 ± .03
Sulphur	---	2.5 per cent Max.
Electrical Resistivity ohms/in.	---	0.0032 Max.

* (Na plus Ca, 0.12 maximum)

Even traces of barium, nickel, titanium, chromium, manganese, cobalt, or vanadium are considered objectionable in the aluminum produced. Comparable specifications on electrode carbon made from coal, by the Germans, were much more liberal with respect to impurities and specific resistivity, and are not reported. It was the specific desire of technical representatives of the aluminum industry of the state that one of the objects of this investigation should be that of producing calcined coal carbon fully equivalent in quality to the petroleum coke in current use (18 October, 1951). Therefore, a sample of current commercial calcined petroleum coke was obtained and analyzed with results as reported in Table III.

A comparison of the results of the foregoing analysis with the typical specifications reveals compliance in all respects. Of note, however, is the fact that the petroleum coke had an actual average specific-resistivity value of 0.00183 ohms/in.^{3}, whereas the typical specification allows values to 0.0032 ohms. In this investigation it was considered necessary to produce coal carbon fully equivalent to calcined petroleum coke. It was believed that reducing the specific resistivity from 0.0032 ohms/in.^{3} to a value of about 0.00180 ohms/in.^{3}

Table III

ANALYSIS OF CALCINED PETROLEUM COKE*

Element	Per Cent by Weight Air Dry Sample; Spectrographic Analysis
Fe	.030
Ca	.040 -
Na	.040
Ca + Na	(.080)
Si	.049
K	.005 -
Al	.012
Ba	.001
Cr	.0005
Co	.001
Cu	.002
Pb	.006
Mg	.006 -
Mn	.001 -
Mo	.001 -
Ni	.050 -
Ag	.0005
Sr	.0005
Sn	.002 -
Ti	.0004 -
Va	.040 -
Total	Less than 0.2789
Specific Resistivity at Room Temperature	0.00175 to 0.00191 ohms/in.^{3}
Ash (Gravimetric A. S. T. M.) (per cent)	0.38
Moisture (per cent)	0.09
Volatiles (per cent)	0.75
Sulphur (per cent)	1.06

*Samples furnished by Kaiser Aluminum & Chemical Corp., Spokane, Washington.

would increase the costs of manufacturing coal carbon two or even threefold. It is clear that the commercial feasibility of producing electrode carbon from coal is directly related to the degree of beneficiation demanded by the aluminum industry and that extremely low-resistivity coal carbon would have a probable cost equal to or higher than petroleum coke unless some new and improved method of beneficiation could be discovered.

The following table lists the relative prices of various types of carbon, and is intended to show the margin which might be allowable to cover the costs of conversion of Washington coal to electrode carbon of petroleum-coke qualities.

Table IV[2]

COST LEVELS OF INDUSTRIAL CARBON

Carbon Type and Point of Origin	Price in Dollars Per Ton		
	Producing Point	Seattle	Spokane
1. Raw Petroleum Coke			
(a) From Casper, Wyo.	$ 8.50 - 14.00	$16.36 - 21.86	$16.36 - 21.86
(b) From Oleum, Calif.	8.50 - 14.00	15.20 - 20.70	18.93 - 24.43
2. Calcined Petroleum Coke			
(a) From Wilmington, Calif.	18.00 - 28.00	25.70 - 35.70	29.43 - 39.43
(b) From Port Arthur, Tex.	18.00 - 28.00	28.80 - 38.80	28.80 - 38.80
(c) From San Jose, Calif.	18.00 - 28.00	24.70 - 34.70	28.43 - 38.43
3. Hard Coal Tar Pitch			
(a) From Chicago area	23.00 - 30.00	42.60 - 49.60	42.60 - 49.60
4. Soft Coal Tar Pitch			
(a) From Chicago area	20.00 - 35.00	39.60 - 54.60	39.60 - 54.60
5. Coal Coke			
(a) From Utah	9.50 - 10.00	16.20 - --	15.70 - 16.20

It was assumed that, if the Germans commercially manufactured coal carbon for electrodes at about three times the cost of coal coke, then similar coal carbon could be made for $30.00 per ton in the Northwest if $10.00 per ton was the cost of coke reported in Washington. Because calcined petroleum coke was available in Washington at $29.00 to $40.00 per ton, it was believed that it would be necessary to construct and operate coal-carbon pilot plants from which dependable cost calculations could be made showing the possible economic advantages of the coal-derived product. Our original research program did not, however, include the budgeting of pilot plants as it was considered necessary to first make preliminary laboratory investigations of the known coal-cleaning methods and, if possible, devise a new means of making low-cost coal carbon equivalent to petroleum coke. Such a process had not been reported in the available literature.

4. Status of the Electrode Carbon Problem in the Pacific Northwest

In the following discussion much has been cited from the Pacific Northwest Field Committee Survey of Industrial Carbon Requirements of the Pacific Northwest.[2] It was believed by this committee that there were some complicated aspects of petroleum refinery practices and economics which could in the future reduce supplies of petroleum coke; but

definite future shortages were not predicted. It was considered that, in general, users of industrial carbon would in the future rely on petroleum coke as an electrode material because "apparently little research has been done on alternate sources of carbon."[12] It was further reported that one of the primary difficulties in solving the electrode-carbon problem was the lack of fundamental knowledge concerning certain types of carbons and their behavior when treated to improve specific desirable characteristics. Charcoal was cited as an example of a possible available material for electrode carbon, but there was little technical data to provide a basis of future development in the Pacific Northwest. Consequently, the Northwest Field Committee proposed a research program including the following recommendations on coal:

(a) Re-examination of the Washington coal fields with a view to their development as a suitable source of electrode carbon.

(b) Provision of programs of investigation of various Northwest coking coals aimed at the application of new heavy-media flotation techniques as well as any other methods recently developed to reduce ash content.

(c) Laboratories of federal and state agencies were urged to make investigations and tests of end products to determine possible use in electro processes. An increase in the available fund of fundamental knowledge was considered an essential for any possible applied investigations.

(d) Analysis of petroleum coke production potentials, with regard to domestic and foreign imports, under conditions of national emergency or peacetime. A comprehensive study of the trends in the refining industry, the relationship between petroleum-coke demands and price levels, and the yields of coke from various crudes and fractions of crude.

(e) Work on fundamental investigations of western coals to determine their peculiarities of response to various schemes of preparation. This was considered necessary as a preliminary approach to larger-scale work programs and pilot-plant development. It was suggested that if sufficient quantities of experimental end products were produced, collaboration with the Northwest aluminum industries should be established with the object of making final service tests of electrodes in actual aluminum reduction.

In the work carried out by the Division of Industrial Research the foregoing suggestions have been followed as far as the limitations of time and budget allocated to this project would permit. It was believed that, although the problems involved in producing satisfactory electrode carbon from Washington coal were extremely vague and complicated, they were not necessarily technical and commercial impossibilities. This view was supported even in the light of the adverse conclusions of technicians claiming that from the cost standpoint beneficiation of Washington anthracite to compete with petroleum coke, was prohibitive.[4] While the resources of anthracite coal within the state were believed to be insufficient to supply the entire future carbon-electrode requirements of the northwest aluminum industry for a very great number of years, the development of even a satisfactory laboratory process was considered as a desirable contribution to the known facts in this field. Extensive basic research was essential if new methods of producing electrode carbon from Washington anthracite, or other coals, could be relied on to become the alternate source of electrode carbon during periods of national crisis, or in the event that petroleum coke became drastically short in supply.

5. Patent Survey

The problem of improving the resistivity of coal carbon was investigated extensively prior to 1910. At that time, however, the desirability and necessity for carbon of high purity as well as low resistivity appears to have been considered as relatively unimportant. In U. S. Patent 538,289, granted to Shrewsbury, a "good quality coal" was calcined for several four-hour periods at temperatures in the range 1371 - 1600°C., in fired ovens to obtain electrode carbon "equal or superior to graphite as an electrical conductor." Specific resistivity values were not stated for the calcined coal referred to. It is believed that the Shrewsbury carbon did not have resistivity values of the same order as present graphite electrodes or even currently calcined petroleum coke, for the reason that following the Shrewsbury process will not result in ultralow-resistivity carbon, or a material of sufficiently low-ash content to be acceptable by the aluminum industry.[13]

In 1909, Hansen, assigned to the General Electric Corporation, U. S. Patent No. 1,037,901, covering the treatment of carbonaceous brushes consisting of coke, graphite, lamp-black, and pitch binder, which, after being fired at 1300 - 1400° C., had the following characteristics:

Apparent density	1.425
Absolute density	2.05
Porosity	30.5 %
Resistivity	0.00163 ohms/in.^{3}
Tensil strength	800 p. s. i.

Hansen found that by baking the carbon at 480° C. to remove nearly all of the volatile material, impregnating the carbon with melted coal-tar pitch, and then firing at 1300 - 1400° C., the above qualities were improved to obtain the following characteristics:

Apparent density	1.66
Absolute density	2.05
Porosity	19.0 %
Resistivity	0.00108 ohms/in.^{3}
Tensil strength	2130 p. s. i.

In U. S. Patent No. 1,317,497, Hinckley claimed production of electrodes by the graphitization of high-ash anthracite coal. Graphitized electrodes are, of course, in extensive use in various electro-chemical industries, and such use suggests the possibility of the establishment of a graphite industry in the Pacific Northwest. Suitable coal may be obtainable in the necessary quantities, and the necessary amount of electric energy required by a large graphite plant could be obtained by further development of Northwest power resources. The aluminum industry, the largest consumer of carbon electrodes in the Northwest, has indicated unwillingness to use graphite electrodes in view of their high thermal conductivity.

Sieurin, in U. S. Patent 1,282,475, proposed electrodes prepared from anthracite coal and coke, neither of which had undergone purification. Dow obtained two patents. In U. S. Patent No 718,437, he described the preparation of electrode carbon in which the carbon particles were permitted to fall through vaporized hydrocarbon binder. In U. S. Patent No. 718,438, the hydrocarbon binder was emulsified and applied to the carbon particles.

In U. S. Patent No. 1,392,267, issued in 1921, Szarvasy claimed a process in which natural gas was cracked at about 950° C. to produce tar and carbon, which was then calcined to produce electrodes. Gardner's high-purity carbon was produced from coke or charcoal by first boiling with sixth normal sodium hydroxide solution, followed by treatment with 36° Be., nitric acid, washing with alcohol and calcining at 1000° C. to 1300° C. It was claimed that best results were obtained if the coke was ground to a very fine powder passing through a 200-mesh-per-inch sieve. The object of the chemical treatment was the removal of silica, calcium oxide, magnesia, alumina, titanium oxide, and similar ash-forming impurities. The extent to which purification was possible by such leaching was not reported. Daniel Gardner applied for his patent October 10, 1927, and it was issued as U. S. Patent No. 1,780,154, on November 4, 1930.

On March 29, 1946, Swallen and Nelson assigned their U. S. Patent No. 2,527,595, to the Great Lakes Carbon Corporation of Morton Grove, Ill. In this patent they reported the results of specific resistivity tests, apparent densities, and crushing strengths for experimental electrodes prepared with thermatomic carbon, channel black, lamp-black, acetylene black, and coke carbon. Such electrodes were baked for eight days at 950° C. and had resistivity values ranging from 0.00270 to 0.0047 ohms/in.^{3}. When graphitized at temperatures in excess of 2000° C. the resistivity values dropped to 0.00027 - 0.00034 ohms/in.^{3} No data on mineral impurities were reported. The Great Lakes Carbon Corporation also holds U. S. Patent No. 2,527,596, issued October 31, 1950, which covers the use of nitronaphthalene and similar nitro-substituted aromatic compounds as means of increasing the density and strength of carbon electrodes. Electrodes of 1.90 density and 19,000 p. s. i. crushing strength, after baking at 1000° C., were made which had the following properties after graphitizing at temperatures in excess of 2000° C.:

Density	1.91
Crushing Strength	10,000 p. s. i.
Resistivity	0.003 ohms/in.^{3}

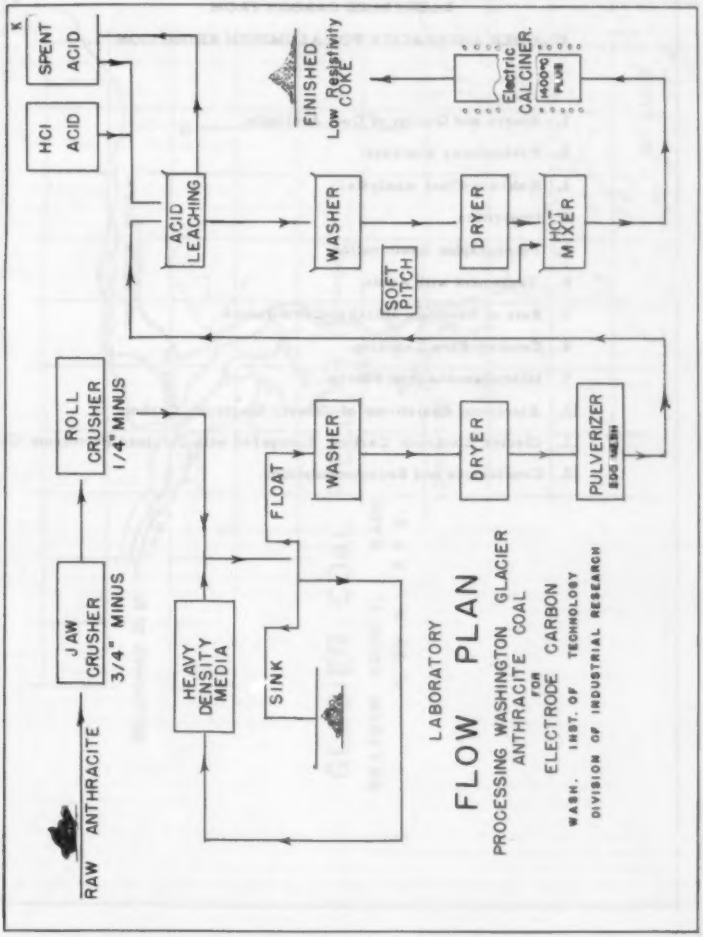
RAW ANTHRACITE
JAW CRUSHER
3/4" MINUS
ROLL CRUSHER
1/4" MINUS
HEAVY DENSITY MEDIA
SINK
FLOAT
WASHER
DRYER
PULVERIZER
HCl ACID
SPENT ACID
ACID LEACHING
WASHER
DRYER
SOFT PITCH
HOT MIXER
FINISHED Low Resistivity COKE
Electric CALCINER.
LABORATORY
FLOW PLAN
PROCESSING WASHINGTON GLACIER ANTHRACITE COAL FOR ELECTRODE CARBON
WASH. INST. OF TECHNOLOGY
DIVISION OF INDUSTRIAL RESEARCH

Figure 1

ELECTRODE CARBON FROM

GLACIER ANTHRACITE FOR ALUMINUM REDUCTION

1. Source and Quality of Coal Available.
2. Preliminary Analysis.
3. Sink-and-Float Analysis.
4. Impurities.
5. Petrographic Examination.
6. Treatment with Acids.
7. Rate of Reaction; HCl-Ash Constituents.
8. Counter-Flow Leaching.
9. Miscellaneous Procedures.
10. Electrical Resistivity of Glacier Electrode Carbon.
11. Glacier Electrode Carbon, Compared with Calcined Petroleum Coke.
12. Conclusions and Recommendations.

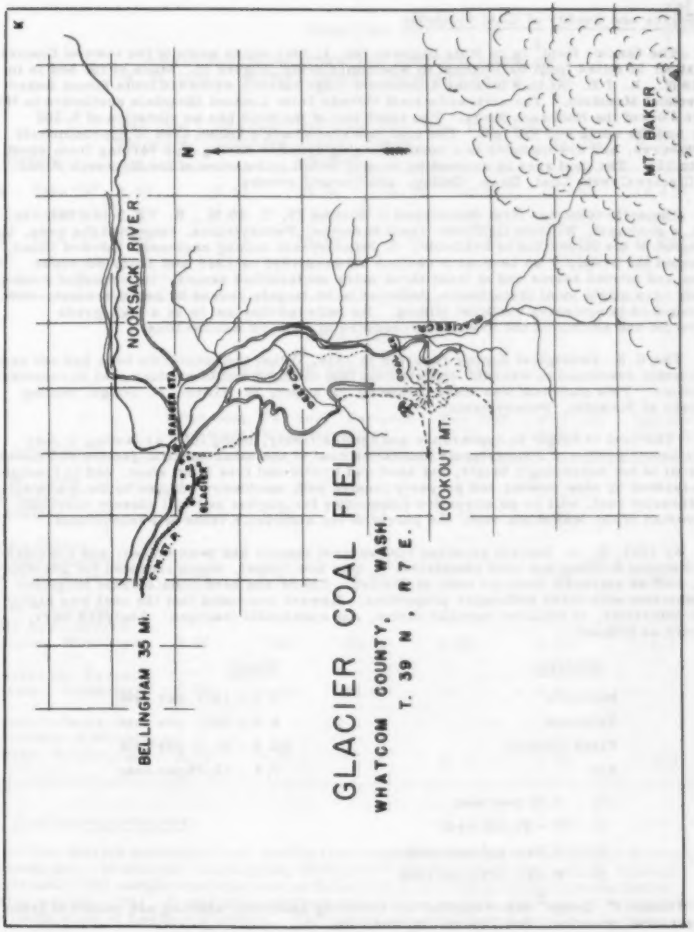
GLACIER COAL FIELD
WHATCOM COUNTY, WASH.
T. 39 N., R 7 E.
N
NOOKSACK RIVER
BELLINGHAM 35 MI.
LOOKOUT MT.
MT. BAKER

Figure 2

1. Source and Quality of Coal Available

The Glacier field[3] is on State Highway No. 1, four miles south of the town of Glacier, and about 32 miles from Bellingham in Whatcom County (Figure 2). Much of the bed is in T. 39 N., R. 7 E. At this location a mountain ridge extends westward from Mount Baker to Lookout Mountain. The anthracite field extends from Lookout Mountain northward to the North Fork of the Nooksack River. The south end of the field has an elevation of 5,200 feet; and the north end 950 feet. The coal measures have a known area of approximately 4,000 acres, and are included in a north-plunging syncline having dips varying from about 32° to 52°. The coal area is drained by several small tributaries of the Nooksack River and Glacier Creek; Coal, Deep, Gallup, and Cornell creeks.

The anthracite was first discovered in Section 29, T. 39 N., R. 7 E., in 1907. In 1908, a geologist, William Griffiths, from Scranton, Pennsylvania, examined the area, but no report of his inspection is available. A Pennsylvania mining engineer, Edward Dinan, examined the property on several occasions between 1910 to 1918 and reported seven known and proved seams and at least three more unclassified seams. He recorded evidence of only very slight local disturbance, believed to be largely caused by heavy erosion, which had resulted in extensive surficial sliding. He believed the coal to be a high-grade anthracite and estimated the available resources at 45 to 50 million tons.

The U. S. Geological Survey reported in 1914,[14] that the anthracite beds had not been sufficiently developed to warrant expectations that the field would produce coal in commercial quantities. This comment was made following the report by William F. Dodge, mining engineer of Scranton, Pennsylvania:

"The coal is bright in appearance and ignites freely, being fully as lasting in duty as the better grades of Pennsylvania anthracite coal of the same specific gravity and density. The coal is not exceedingly bright, but hard and brittle and free from smut, and in fracture; when blasted by slow powder and properly treated with machinery adapted to the manufacture of anthracite coal, will be an attractive commodity for market and will closely resemble the product of the Mammoth vein, the purest of the anthracite veins of Pennsylvania."

By 1923, C. A. Stewart reported that several tunnels had been driven, and considerable diamond drilling had been completed.[15] One new tunnel, which extended for one-fourth mile, had its entrance near the town of Glacier. There had been considerable litigation in connection with these anthracite properties. Stewart concluded that the coal was high-grade anthracite, of brilliant metallic lustre, and conchoidal fracture. Analyses were reported as follows:

Analysis	Range
Moisture	0.7 - 10.7 per cent
Volatiles	6.9 - 16.0 per cent
Fixed Carbon	68.0 - 91.9 per cent
Ash	7.4 - 12.79 per cent

H - 2.97 per cent
C - 77 - 93 per cent
S - 0.94 - 1.2 per cent
N - 0.98 - 1.17 per cent

William F. Dodge[3] also reported the following analyses, showing ash values of from 1.67 per cent upwards: See Tables I (a) and I (b).

It appeared from these analyses that an appreciable proportion of the Glacier anthracite would contain less than 5-per-cent ash, and fixed carbon in excess of 85 per cent. For these reasons, it was considered that Glacier anthracite might be a suitable carbon source for electrodes used by the aluminum industry.

Table I (a)

ANALYSES OF GLACIER ANTHRACITE MADE BY
W. H. DEAN, WILKES-BARRE, PENNSYLVANIA, 1908

Sample	Per cent Moisture	Per cent Volatiles	Per cent Fixed Carbon	Per cent Ash	Per cent S	Sp. Gr.	B. T. U.
"K", Vein "A"	1.42	7.57	74.06	16.95	0.91	1.552	12,693
"L", Vein "A"	2.07	6.74	89.52	1.67	0.79	1.441	14,515
"M", Vein "A"	1.88	7.72	84.86	5.54	1.21	1.474	14,241
"N", Vein "A"	2.02	8.78	83.88	5.32	0.99	1.465	14,241

Table I (b)

RESULTS OF VARIOUS ANALYSES

Laboratory	Per cent Moisture	Per cent Volatiles	Per cent Fixed Carbon	Per cent S	Per cent Ash	Specific Gravity
C. W. Drew Minneapolis, Minnesota	1.70	7.50	85.61	0.68	4.51	--
Peter Daley Tacoma Smelter Tacoma, Wash.	1.09	5.91	88.00	--	5.00	1.440
R. W. Thatcher State Agriculturist Pullman, Washington	0.88	7.20	86.36	0.65	4.94	1.478
Charles M. Fassett Spokane, Washington	2.70	6.99	84.44	--	5.87	--
Milnor Roberts University of Washington Seattle, Washington	1.75	6.10	87.76	0.53	3.86	1.460

2. Preliminary Analysis

The Glacier anthracite coal used in these experiments was obtained from Western Carbon, Inc., of Seattle, Washington, through the efforts of Mr. Richard E. Randall, President. The sample was taken by an Industrial Research Division representative during August, 1951. It was obtained from the surface near the entrance of the tunnel on the north slope of Lookout Mountain. The tunnel had caved in and could not be entered.

Analysis by A. S. T. M. Method D 271-44 was made with the results shown in Table II. Spectrographic analysis indicated less than .005 per cent each of the following elements in the coal: Barium, Boron, Chromium, Cobalt, Copper, Lead, Manganese, Molybdenum, Nickel, Phosphorus, Potassium, Silver, Strontium, Tin, Titanium, Vanadium, and Zinc. It is believed that the major ash-forming constituents probably exist in the coal as calcite, pyrite, and kaolinite, with some prochlorite.

Table II

ANALYSIS OF GLACIER ANTHRACITE COAL
(Sample of August 1951)

	Air-Dry Basis	Dry-Coal Basis
Moisture per cent	0.80	---
Volatiles per cent	4.29	4.32
Ash per cent	4.18	4.21
Fixed carbon per cent	90.73	91.46
Apparent Density	1.405	---
S per cent	1.04	---

The 4.18-per-cent ash was analyzed with the following results:

	Per cent of Ash
SiO_2	12.6
Al_2O_3	35.9
Fe_2O_3	13.7
CaO	9.4
MgO	16.1
SO_3, TiO_2 and Undetermined	Balance

3. Sink-and-Float Analysis

Specific-gravity analysis made by immersing a sample of the coal in a series of float-and-sink liquids of increasing specific gravity and removing the floating fractions for further analysis has long been the standard procedure for evaluating the washability characteristics of coals, and was utilized in this investigation. Frequently the coal is sized by screening to such sizes as 1/2 inch - 1 inch mesh; 1/4 - 1/2 inch mesh; 1/8 - 1/4 inch mesh; and 1/8 inch minus; and each of these fractions analyzed by the sink-and-float technique. In this investigation it was desired that the greatest possible yield of ultraclean coal be obtained from the raw coal without discarding large portions of certain-sized raw coal. The method used is described fully in handbooks on ore dressing. [16, 17] The Glacier coal crushed to 1/4 inch mesh (minus)*, was floated on aqueous solutions of zinc chloride with results as shown in Table III.

These results are presented graphically in Figure 3. In the study of data as reported above, it is helpful to make use of the beneficiation index, T. This index is considered as a rough criterion of the difficulty which may be expected in heavy-density, float-type beneficiation.

$$T = \frac{P \times 100 \times B}{Ad}$$

Where:

P = Theorectical yield of floated coal, as per cent by weight of total coal treated at density d.

Ad = Dry basis ash content, per cent, at density 1.42.

B = Per-cent yield of float coal at density 1.8.

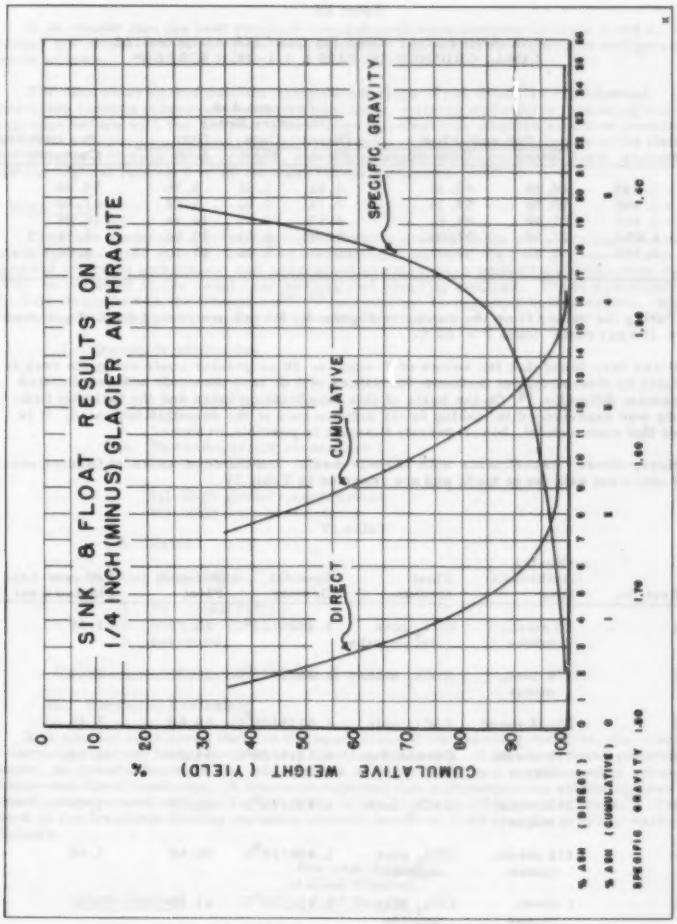
SINK & FLOAT RESULTS ON
1/4 INCH (MINUS) GLACIER ANTHRACITE
CUMULATIVE WEIGHT (YIELD) %
0
10
20
30
40
50
60
70
80
90
100
DIRECT
CUMULATIVE
SPECIFIC GRAVITY
% ASH (DIRECT)
% ASH (CUMULATIVE)
SPECIFIC GRAVITY 1.60
1.70
1.80
1.40

Figure 3

Table III

SINK-AND-FLOAT TEST ON GLACIER ANTHRACITE COAL, CRUSHED TO PASS A 1/4-INCH SCREEN*

Specific Gravity	Per cent Float		Per cent Ash (Moisture Free) Direct Float	Cum. Float	Cum. Sink	Per cent Sink Cumulative
	Direct	Cumulative				
Under - 1.430	40.16	40.16	1.82	1.82	5.76	59.84
1.430 - 1.440	18.00	58.16	3.11	2.22	6.84	41.84
1.440 - 1.460	25.00	83.16	4.59	2.93	10.34	16.84
1.460 - 1.650	13.90	97.06	6.34	3.41	29.60	2.94
1.650 - 1.770	2.36	99.42	25.97	3.95	43.10	0.58

Taking the values from the curves in Figure 3: P = 45 per cent; Ad = 2.0 per cent; and B = 100 per cent. Then T = 22.5.

It has been found that for values of T equal to 20 or greater coals are quite easy to beneficiate by sink-and-float methods; for values of 5 or less the coals are beneficiated with greatest difficulty.[18] On the basis of this beneficiation index and the fact that little difficulty was experienced in making fairly definite cuts at the densities indicated, it is believed that commercial, heavy-density flotation is possible.

Heavy-density experiments with various media, and different sizes of Glacier coal of 4.18-per-cent ash, were made and are reported in Table IV.

Table IV

Test No.	Glacier Anthracite Size	Float Medium	Specific Gravity	Per cent Float	Per cent Ash Floated Coal
1	20 mesh, minus	CCl_4 plus Pet naphtha	1.4080/23°C	36.30	1.38
2	1/8 inch, minus	$ZnCl_2$ soln.	1.4005/25°C	11.75	1.47
3	20-28 mesh	$ZnCl_2$ soln.	1.4115/25°C	59.60	2.19
4	1/8 mesh, minus	Carbon Tet.	1.4115/23°C	44.25	1.34
5	1/2 mesh, minus	$CaCl_2$ Soln.	1.402/35°C	40.55	1.76
6	1/2 mesh, minus	CCl_4 plus naphtha	1.408/20°C	36.60	1.60
7	1 mesh, minus	CCl_4 plus naphtha	1.412/25°C	41.80	2.15
8	1 mesh, minus	CCl_4 plus naphtha	1.400/25°C	12.85	1.29

*All screen sizes in this report are based on the use of Tyler sieves.

It is evident that the best yields of low-ash coal were obtained in tests 1 and 4, using 20-mesh and minus 1/8-inch mesh, coal floated on the carbon tetrachloride and petroleum naphtha mixture.

The zinc chloride and calcium chloride solutions of the densities used formed appreciably viscous dispersions with the coal fines, causing difficulties in making very sharp separations with the screen. The carbon tetrachloride-naphtha mixtures resulted in less viscous dispersion of fines, and allowed ready separation and recovery of the float coal. Coal of 1/8-inch mesh or finer, but without excessive amounts of fines, appeared to allow the highest recovery of ultraclean Glacier anthracite.

4. Impurities

From the viewpoint of cleaning and de-ashing coal, both the ash-forming and sulphur-containing impurities may be classified as structural parts of the coal homogeneously dispersed (inherent impurities) and segregated or extraneous impurities which may, to some extent, be removed by the usual coal washing and cleaning methods. These processes have been fully described in the literature[19, 20] and will not be repeated in this report. Most of the coal-cleaning processes may be classified as follows:

I. Gravity Stratification

A. Wet Process

1. Jigs
2. Launders
3. Upward-current classifiers
4. Heavy Mediums

(a) High-density suspensions
(b) High-density solutions

5. Tables

B. Dry Processes

1. Pneumatic tables
2. Air jigs
3. Air-sand

II. Non-gravity process -- froth flotation

III. Chemical Treatment

It is usually considered that, in the application of the washing methods, the inherent ash-forming material is approached as a limiting minimum. It has been found possible, however, to greatly decrease the inherent ash of some coals by a combination of screening and sink-and-float treatment. It has been reported that a Pennsylvania anthracite was crushed and screened on 1, 1/2, 1/4, 1/8, 1/16, 1/32 and 1/64 mesh screens.[21] The ash content of the fractions floating on heavy-density liquid of 1.30 specific gravity, varied as follows:

Mesh (inches)	Per cent Ash of Coal Floated at 1.30 Sp. Gr.
1	5.2
1/2	4.3
1/4	4.3
1/8	3.4
1/16	3.0
1/32	2.4
1/64	1.5

To some extent the screening operation may separate the coal into different petrographic constituents. The ash differences may also be due to the increase in specific gravity of the smaller particles by sorption of salt from the solutions used. It was observed that there was some variation in yields with different sizes of the Glacier anthracite when floated on salt solutions and mixtures of carbon tetrachloride and naphtha. When no salt is used the sorption effect is minimized. It is believed that when the coal particles are very near the density of the salt solution, absorption of salt by such high-ash particles may increase their density causing them to sink. A further variable is introduced by the difference in porosity of the coal particles. No extensive investigation was made on the effects of particle size on impurity removal from Glacier anthracite since it was considered that the sink-and-float results obtained and shown as Tests 1, and 4, Table IV, were acceptable in the preliminary investigation as to yield and ash value. With Glacier coal of higher ash value (5 to 9 per cent), it would be desirable to explore more fully the problem of fines and coal size with regard to the ash content of floated fractions.

5. Petrographic Examination

The ash analyses indicated the quantity and nature of the inorganic elements in the coal, but, of course, did not show the distribution of the mineral matter throughout a sample. Most of the prepared samples viewed under a petrographic microscope at magnification of 240 and 480 diameters showed no apparent banding, and only small amounts of mineral, ash-forming material. In some of the samples, it was possible to see what was considered to be pyrite (FeS_2) and calcite ($CaCO_3$). The minerals appeared mostly as exceedingly fine particles lying in lines in fine cracks on folds in the anthracite. In general, the coal appeared to be homogeneous with regard to foreign material.

From the data shown in the chemical analyses of the Glacier anthracite and in view of data found in the literature on this subject,[22] it is considered that this coal may contain kaolin ($Al_2O_3 \cdot 2\,SiO_2 \cdot 2\,H_2O$), quartz ($SiO_2$), prochlorite ($2\,FeO \cdot 2\,MgO \cdot Al_2O_3 \cdot 2\,SiO_2 \cdot 2\,H_2O$), limonite ($2\,Fe_2O_3 \cdot 3H_2O$), magnetite ($Fe_3O_4$), gypsum ($CaSO_4 \cdot 2H_2O$) and possibly muscovite ($KNaO \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$). The trace elements shown by the spectograph are considered relatively unimportant from the quantitative standpoint, since nearly 90 per cent of the ash consisted of alumina, silica, iron oxide, calcium oxide, and magnesia. It is likely that much of the pyrite, calcite, kaolinite, or gypsum found in the shrinkage cracks, fusion cavities, or cleats form a large portion of the 4.18 per cent of ash in this coal. Most of this material was laid down late in the coal-forming process, but appears quite uniformly distributed. The mineral matter is mostly foreign to the organic material from which the coal was formed and may be adventitious or detrital clay washed into the peat bog prior to anthracite formation.

The petrographic components of coal are vitrain, clarain, durain, and fusain (or anthraxylon). These organic components of coal are known to be characterized by the amount and type of ash-forming constituents they contain. Fusain may contain from 0.8 to 3 per cent of ash. It has been reported[23] that the high percentage of water solubles, and low amount of HCl insolubles in the ash from clarain and vitrain, prove that they represent the original plant ash. For a given coal, the ash contents of the petrographic components ordinarily will increase in the following order: vitrain, clarain, durain, and fusain. The Glacier anthracite consists chiefly of vitrain. Float fractions containing 1.29 to 1.47-per-cent ash are considered to some extent as concentrations of vitrain from this coal. Lessing[23] has reported ash contents as follows for the petrographic components of an English coal: fusain, 15.59 per cent, durain 6.26 per cent, clarain 1.22 per cent, vitrain 1.11 per cent.

Many investigators have suggested flotation as a means of separating the petrographic constituents of coal, which in turn would yield fractions of different ash content. This work is discussed fully in the following patents:

U. S. Patent 1,499,872 (1924), Price, F. G.
U. S. Patent 1,944,529 (1934), Schaefer, W., Mertens, W.

French Patent 743,295 (1933)
German Patent 619,239 (1935)
German Patent 650,031 (1937)

The German patents proposed a method of selectively froth-floating fusain, which was based on the preferential surface oxidation of the different petrographic substances. From 250 to 500 grams of potassium permanganate per ton of coal were added to the flotation medium and were intended to cause more or less oxidation of the humates in the durain, clarain, and vitrain. The humic acid formed hydrophilic surface layers on the coal particles and caused them to be depressed, whereas fusain of lower humate was less affected and floated off by the frothing agent. A further separation of coal from refuse was then made by application of a stronger frothing agent, which was relatively unaffected by the hydrophilic tendencies promoted by the oxidation. This procedure is of considerable interest in the event that further investigation warrants consideration of coals not readily de-ashed to values of 1.5 per cent or less by established commercial processes.

A German process[24] has been investigated, in which the petrographic constituents (fusain, durain, and vitrain) were separated by being subjected to resilient disintegration or shattering action for a sufficient length of time to break the constituents into granules of various sizes depending on their respective resistances to shattering impact. The coal granules were then screened to sizes of 3.15-inch mesh, 0.16-inch mesh and fines of minus 4 mm. It was claimed that an enriched coal containing 80-per-cent vitrain and 19-per-cent durain with less than 1 per cent of fusain representing about 42 per cent of the head coal was produced.

6. Treatment with Acids

As mentioned in the introduction, German investigators as well as the U.S. Bureau of Mines,[6] have reported the use of acids for removing ash-forming materials. Both dilute hydrochloric acid and hydrofluoric acid used separately and in combination have been utilized by other investigators. From the literature it was found that percentagewise it was possible to remove more of the mineral constituents from brown coals than from bituminous coals or anthracites. This has been attributed partly to the greater degree of porosity in the lower-ranking coals, which may permit a greater area of contact by the acid and deeper penetration of the coal particle. It was reported that, for the lower-ranking coals, the calcium and other minerals are organically bound to a much greater extent than in the higher-ranking anthracites.

In Glacier anthracite, the chemical composition of the impurities and their physical distribution indicated the necessity for removal of both inherent and extraneous minerals if coal of less than 0.50-per-cent ash was to be made.

(a) Leaching Tests on Non-beneficiated Glacier Anthracite. A few tests on the raw Glacier anthracite and the modified coal were made to determine the effects of direct acid treatment on the whole coal and are reported in Table V. All of the experimental leaching tests were made in Pyrex beakers heated by an electric hot plate; the reaction mixture was agitated moderately with a small, motor-driven glass propeller. Following the acid treatment, the coal was washed three times on a Buchner funnel and dried at 100° C. until no further weight loss was noted. The ash values are therefore based on a moisture-free condition.

It was evident from these experiments that direct treatment of the coal with 2N HCl, as shown, would not accomplish reduction of the ash content to a value of 0.50 per cent or less. In general about one-half of the ash was removed by the hot hydrochloric acid treatment. In view of these results it was decided to continue the experiments with HCl leaching, but substituting the float-beneficiated coal for the raw coal.

(b) Acid Leaching, Floated Glacier Anthracite Coal. Results of these experiments are reported in Table VI.

From the foregoing data it was seen that leaching with 2N hydrochloric acid would remove about two-thirds of the ash constituents, when the ash value of the floated coal was in the 1.34 to 2.05-per-cent range. Important variables were considered as being (a) ash value of the floated coal, (b) time of treatment, and (c) state of division of the coal being leached. It was desirable to grind the coal to minus 100 mesh for acid leaching and utilize a heavy-density medium such as carbon-tetrachloride and naphtha to produce a yield of about 40 per cent of floated coal having an ash value 1.35 - 1.45 per cent. The final leached

Table V

HYDROCHLORIC ACID
LEACHING TESTS ON GLACIER ANTHRACITE

(Raw Coal ground to 100 mesh/inch, minus)

Sample No.	Nature of Treatment	Per cent Ash Before Treatment	Per cent Ash After Leaching	Amount and Strength of Acid	Temp. °C.	Time Hours
4- 2	Direct leach	4.22	2.27	Excess 2N HCl*	80-100	1
4-2a	Retreatment of sample 4-2	2.27	1.90	Excess 2N HCl*	80-100	1
4- 3	Calcined at 1300°C. 2 Hr., then HCl leached	4.22	2.12	Excess 2N HCl*	80-100	1
4- 4	4-2 Calcined at 1300°C. with soda ash	4.22	2.42	Excess 2N HCl*	80-100	1
4- 5	20% of equal parts of HCl (36% HCl) and HF (46%)	4.22	2.78	Excess 2N HCl*	40	1
4-15	65 mesh coal, HCl leached	4.22	2.19	Excess 2N HCl*	80-100	4
	Retreatment of 4-15	2.18	2.20	Excess 2N HCl*	100	4

* 1000 ml. 2N HCl/100 gr. of coal.

Table VI

RESULTS OF HCl TREATMENT OF FLOATED GLACIER ANTHRACITE

(Per-cent Ash, Raw Coal, Series 4 = 4.22%; Series 3 = 4.18%)

Sample No.	Per cent Yield of Floated Coal	Per cent Ash Floated Coal	Per cent Ash HCl Treated Coal	Strength of HCl	Temp. °C.	Time Hours	Mesh/in. of coal leached
4- 6	11.75 (2)*	1.47	0.32	2 N**	80-100	2	30 minus
4- 9	44.25 (4)	1.34	0.55	2 N**	80-100	3	1/8 minus
4-12	36.30 (1)	1.38	0.36	2 N**	80-100	3	20 minus
1-18	12.85 (8)	1.29	0.49	2 N**	80-100	3	50 minus
2-21	40.55***	1.76	0.70	2 N**	80-100	4	100 minus
		(Retreat 2-21)					
2-23	40.55	0.70	0.43	2 N**	80-100	20	100 minus
2-27	40.50	2.05***	0.82	2 N**	80-100	8	100 minus
2-32	36.60 (6)	1.60	0.45	2 N**	80-100	10	100 minus

Note: The loss of weight, on acid leaching was less than 5%.
* = Numbers in ( ) refer to Table IV.
** = 1000 mL 2 N HCl/100 gr. coal.
*** = Floated on $CaCl_2$.

product had 0.36 to 0.49-per-cent ash. It appeared desirable to obtain further data on the rate of reaction between HCl and the ash-forming constituents as well as determining, if possible, the practicability of counterflow treatment of the coal with very dilute acid.

Chemical analyses by the usual quantitative methods were made on the ash material from raw Glacier anthracite and the floated and the acid-treated products with results as shown in Table VII.

Table VII

CHEMICAL ANALYSES OF ASH FROM TREATED AND UNTREATED GLACIER ANTHRACITE

	Head Raw Glacier	Float	Float	Float	Direct HCl Treated	Float HCl Treated	Float HCl Treated	Max. Specified (Calcined Basis)
Sample No.	3	3-2	3-6	4-1	4-26	2-23	4-11	
Per cent Yield (Moisture Free)	(100)	40.16	2.36	11.75	95	40.55	44.25	
Per cent Ash	4.18	1.82	25.97	1.47	1.87	0.43	0.55	0.50
Ash Analysis								
SiO_2	12.6	9.1	1.0	9.2	12.2	7.6	8.8	
Al_2O_3	35.9	29.0	18.1	19.6	52.0	40.6	48.5	
Fe_2O_3	13.7	6.8	66.2	13.0	12.5	10.3	5.1	
CaC	9.4	-	1.4	16.3	3.5	7.4	9.6	
MgO	16.1	-	5.1	24.6	4.2	10.2	11.8	
Mineral Impurities (Per cent of Coal)								
Si	.246	.077	.121	.063	.107	.015	.022	.06
Fe	.400	.086	12.024	.133	.163	.031	.019	.06
Ca	.281	.192	.259	.171	.047	.022	.037	.12
Mg	.406	-	.798	.218	-	-	.039	
Al	.794	.279	2.480	.152	.514	.092	.141	
Na	-	-	-	-	-	-	-	.12

These analyses show that it was not possible to meet the 0.50-per-cent-maximum ash requirement or the detail requirements for silica, iron, or calcium by the sink-and-float procedure alone. By leaching the floated coal with 2N HCl, all of the mineral impurity requirements were readily complied with, even after correction for those slight increases in ash constituents which would occur when driving off the 4.32 per cent of volatiles in calcining the final product.

It was noted that the aluminum content of the floated acid-treated coal was in the 0.092 - 0.141-per-cent range; and, although as was anticipated, the alumina was least reactive in the leaching procedure followed, more than half the alumina was removed by the sink-and-float treatment, except in highly mineralized fraction 6. Alumina as such is not restricted in the specification. It is believed that the high iron content of sample 3-6 (the 1.650-1.770 sp. gr. fraction representing only 2.36 per cent of the coal, Table III, 66.2-per-cent Fe_2O_3 based on the ash) occurred mostly as pyrite. Because of its high specific gravity, much of the pyrite was concentrated in the final, heaviest float fraction.

7. Rate of Reaction; HCl-Ash Constituents

In the work done by the U.S. Bureau of Mines, 60-mesh coal was treated for 24 hours, at room temperature, with a weight of 10-per-cent HCl solution equal to the weight of coal. As no other literature references were available showing the rate of the reaction of ash constituents with HCl, experimental work was performed to evaluate this important factor.

As a starting point, it was assumed that a typical, floated Glacier anthracite (about 40-per-cent yield) would contain: 0.1 Fe, 0.2 Ca, 0.2 Mg, 0.05 Na, and only small quantities of other constituents, which would react with the HCl. It was computed that 1.129 parts of HCl would be required theoretically for combination with the minerals in 100 parts of such coal. In the laboratory procedure, 57 grams of sample 2-27, floated coal, were agitated at room temperature in 7-liter, widemouth Erlenmeyer flasks, utilizing the Fisher Gyrosolver to impart a moderate, swirling-type agitation to the flask contents. The acid solution consisted of 200 ml. of distilled water to which 1.129 grams of HCl had been added, the total solution volume being 207 ml. Five ml. samples were taken for determination of HCl at various intervals.

Table VIII

RATE OF LEACHING TESTS

Run No.	2-27A	2-27AA	2-27B (Retreat of 2-27A)
Per cent Ash Before Leaching	2.05	2.05	0.74
Grams HCl at start of leach	1.129	1.129	1.129
Grams HCl Consumed:			
Time: 1/2 Hours	.420	.437	.187
2 Hours	.590	.586	.206
3 Hours			.220
5 Hours			.224
8 Hours			.222
19 Hours			.247
48 Hours	.8613	.8380	
53 Hours	.8951	.8640	
Ash after Leaching, per cent	0.74	0.73	0.61
Gr. Ash Removed per Gr. HCl consumed	0.83	0.87	0.27
Per cent of Ash Removed	63.8	64.4	17.5

These tests showed that with 75 per cent excess HCl, the ash content was reduced from 2.05 per cent to 0.74 per cent (64 per cent of the total ash was removed) in 53 hours. Equilibrium was not established in this period of time although 79 per cent of the acid was consumed; and, when acid consumption was plotted against time on log-log paper, fairly

straight lines were obtained. This coal was again treated with HCl and a further reduction of 0.13-per-cent ash was made. It appeared from these results that the reaction rate, as studied herewith, was roughly similar to that reported in Table VI, using 2N HCl in great excess and volume. For example, in sample 2-27, 55 per cent of the ash of this same coal was removed in ten hours by 2N HCl at 80-100°C. As previously mentioned, if it is desired to produce, by acid leaching, Glacier anthracite of less than 0.5-per-cent ash, and the coal should be previously beneficiated to the 1.35-1.45-per-cent ash range.

It was considered that in this investigation it was unnecessary to carry the work to the point of definite determination of the reaction order and reaction constants. It must be realized that the reaction between the disseminated minerals in this anthracite coal and the aqueous HCl solution is definitely in the class of heterogeneous systems and is exceedingly complex as the HCl reacts with at least four different compounds. The reactions occur between solids and a liquid phase, and in general are affected by the following factors:

(a) Area of surface in contact with the HCl solution (porosity and size of coal).

(b) The temperature of the system.

(c) Diffusion velocity of the reactant materials at the solid-liquid interface. This is greatly retarded by the coal substances.

(d) Pressure. By the treatment of the coal in an autoclave at temperatures in excess of 100°C., reaction would tend toward greater completion in decreased time.

(e) Acid Concentration. As is often the case in heterogeneous reactions, the rate of reaction was relatively independent of acid concentration for the range of concentrations used.

(f) The reaction rate was greatly retarded in the anthracite samples which had been previously acid leached. The quantity, chemical nature of unreactive ash-forming constituents, and their dissemination tend to make these remaining materials more difficult to leach when treated a second time.

8. Counterflow Leaching

In view of the heterogeneous nature of the leaching reaction and the need for information on the effects of the partly spent acid on final removal of the mineral constituents, some simple batch-type counterflow leach tests were made using the similar procedure and apparatus as in the rate of reaction experiments, Part 7.

(a) Fifty grams of sample 3-2 (minus 65 mesh) were agitated with 1 gram of HCl and 200 ml. of distilled water for 8 hours. The aqueous phases were tested for acidity and the final filtrates were analyzed.

(b) The washed coal from (a) was leached again with 1 gram of fresh HCl, and the filtrate used for leaching a fresh 50-gram sample of coal (c).

(c) Fifty grams of fresh coal was leached with the spent acid (filtrate) from (b). The filtrate from leach (c) was analyzed.

(d) The washed, treated coal from (c) was leached with 1 gram of fresh HCl. The washed and dried coal was run for ash content.

(e) The filtrate from (d) was used for leaching a fresh sample of coal, and the leached coal and filtrate were analyzed.

From the data obtained and reported in Table IX, it was evident that under counterflow conditions nearly all of the HCl in the spent leach acid combined with the powdered coal and its minerals. For instance, in Run C, the calculation, $\frac{0.7240}{0.744} \times 100 = 97.4$ per cent, shows that 97.4 per cent of the HCl in the spent acid was consumed, leaving the HCl concentration of the twice-used solution at the very low value of only 0.010 per-cent HCl.

Table IX

HCl CONSUMED IN BATCH-COUNTERFLOW LEACH TESTS

(50-gram samples, 200 ml. H_2O, HCl as reported)

Run	A	B	C	D	E
Grams HCl at start	1.000	1.000	0.744	1.000	0.7730
Per-cent Ash at start	1.82	0.65	1.82	1.080	1.82
Grams HCl Consumed at time:					
1 Hour	0.4635	0.1880	0.3890	0.1420	0.5173
2 Hours	0.5532				
3 Hours		0.2353			
5 Hours			0.5257		
7 Hours		0.2278		0.1722	
8 Hours			0.6825		0.7248
9 Hours				0.1862	
13 Hours	0.6842				0.7518
40 Hours			0.7240		
Per-cent Ash, Leached Coal	0.65	0.61	1.08	0.99	0.97
Per-cent Ash Removed	1.17	0.04	.74	0.09	.85
Per-cent of Total Ash Removed	64.2	6.1	40.7	8.3	46.7
Grams Ash Removed per Gram HCl Consumed	0.85	0.09	0.51	0.24	0.57

In Test E, the final acidity of the spent leach solution was also 0.010-per-cent HCl. These tests show the practicability of nearly total HCl consumption in a properly designed and operated counterflow leach plant. It is believed that coal treated with HCl tends to hold chlorine either in a physically or chemically-bound condition, and the quantity held may amount to as much as 0.40 per cent by weight.[24] In the interpretation of HCl consumption data this phenomenon should be given due consideration.

It is of note that, with 5-per-cent HCl solution in excess, the fresh coal was leached at the rate of about 0.85 lbs. of ash (removed) per pound of HCl consumed in a 13-hour period. As previously discussed, during the second stage of the leach, the reactants require a greater proportion HCl for a unit of ash removed. A comparison of the data covering this point is presented in Table X.

It is shown by the data that only about one-third of the ash was removed, for consumption of one pound of acid in retreatment (2nd stage) as when both fresh coal and fresh acid were used in the first stage. Mineral impurities requiring a greater proportion of acid, which may have slower reaction velocities, offer a possible explanation. It is also possible that increased reaction of HCl with the coal substances during second-stage leaching may be involved.

The total HCl required for leaching the suitably float-beneficiated Glacier anthracite should not be greater than 2 lbs. of HCl per 100 pounds of coal. At the rate of 40 lbs. of HCl per ton of coal, and HCl valued at 5.2 cents per pound, the cost of this chemical for leaching was estimated at $2.08 per ton of coal. (Cost of 20° hydrochloric acid was taken at $33.00 per ton.)

9. Miscellaneous Procedures

In the search for the most suitable method for de-ashing the Glacier anthracite a wide variety of ideas and proposals were considered and rejected. In a few instances, laboratory experiments were made with a view toward exploring the possibilities. Brief comments on some of the various ideas are listed below.

Table X

SUMMARY OF RESULTS SHOWING HCl CONSUMPTION AND ASH REMOVAL IN FIRST AND SECOND STAGES OF LEACHING

(1st Stage; Fresh Acid, Fresh Coal. 2nd Stage; Fresh Acid, Treated Coal)

	Lbs. of Ash Removed per Lb. of HCl Consumed		Lbs. Acid Consumed per 100 lbs. of Coal	
	Stage 1	Stage 2	Stage 1	Stage 2
Runs 2-27AA and 2-27B	0.87	0.27	1.51	0.48
Runs A and B	0.85	0.09	1.37	0.44
Runs C (spent acid) and D	0.51	0.24	1.45	0.37
Average	0.74	0.20	1.44	0.43

(a) Electrostatic Process.[9] This method has been developed by German scientists. Its proponents have claimed that coal of 8 to 10-per-cent ash content, has been de-ashed to values of 1.5 to 4 per cent. The process has been offered for the beneficiation of coal, by the Lurgi-Apparatebau-Gesellschaft M. B. H., Frankfurt A. M., Germany. The extent to which the processes will de-ash coal is subject to the many variables characterized by the nature, dissemination, and constitution of the ash-forming constituents. Since it was considered doubtful that the ash value of the Glacier coal could be reduced electrostatically to 0.5 per cent or less, tests with this elaborate and costly device were deferred.

(b) Calcination of the Anthracite Followed by HCl Leaching. Glacier anthracite was powdered and calcined in a crucible in an electric resistance furnace for 2 hours at 1300° C. Prior to calcination the coal contained 4.18-per-cent ash. Following the calcination, the coal was leached for 1 hour with an excess of 2N HCl at 80° C. The leached coal had an ash value of 2.12 per cent as compared with a blank sample which was not calcined and had 2.27-per-cent ash. Considering the fact that loss of volatiles tends to increase the ash values, it was noted that a definite but not extensive reduction in ash was obtained. Calcination of the powdered coal no doubt increased the porosity of the anthracite particles, thus increasing the area which could be contacted by the acid solution. The results were of insufficient scope to warrant further detailed investigation.

(c) Calcination of Coal with Soda Ash, Followed by HCl Leaching. One hundred grams of 590-micron (minus) Glacier coal (4.18% Ash) were mixed with 30 grams of soda ash and 30 grams of H_2O, dried, and then calcined for 2 hours at 1300° C. It was anticipated that some fusion or combination with mineral matter in the coal might permit improved ash reduction in subsequent acid leaching. The results showed the ash value after leaching was 2.42 per cent as compared with 2.27 per cent for the blank, and were unfavorable. It is possible that some compounds nonreactive with the acid were formed or that porosity was decreased.

(d) Froth Flotation. No extensive study of flotation properties of the Glacier coal was made; however, it was considered that investigation of these properties, combined with a program of partial oxidation or other treatment of the coal prior to flotation, would prove to be of interest. Twenty-mesh Glacier anthracite (without other agents or depressants) was treated in a laboratory flotation cell using cresylic acid as the flotation agent. A yield of 30.7 per cent of float coal of 3.04-per-cent ash was produced from coal originally having a 4.18-per-cent ash value.

(e) Combinations of Acid and Alkali Leaching. A 36.3-per-cent yield of minus 20-mesh-float coal was accomplished using a mixture of carbon tetrachloride and petroleum naphtha (sp. gr. 1.308 at 23° C.) as the heavy-density media. This float coal had an ash value of only 1.38 per cent and, after leaching with 2N HCl for 3 hours, washing and drying, its ash value was 0.36 per cent. This coal was then boiled with 5 times its weight of 3-per-cent NaOH solution, washed, and treated with 2N HCl for 2 hours. The final ash content, 0.42 per cent, showed the negative effects of alkali on the final de-ashing of this anthracite. This result, to some extent confirms the results obtained in paragraph (c), which describes the experiment with soda ash; both procedures tend to show an increase in ash rather than appreciable de-ashing. This effect, although not fully understood, may depend on the decrease of porosity caused by the closing of the coal capillaries by products of reaction between the coal substances and alkali.

(f) Leaching with Nitric Acid. In considering the various reagents for leaching, the following were believed of most importance: HCl, HF, HNO_3, and H_2SO_4. In view of the possibility of forming water-insoluble sulfates, such as $CaSO_4$, which could remain in the pores of the coal particle and hinder de-ashing, no leach tests were made on Glacier coal with H_2SO_4. HF was considered too costly and dangerous for commercial use.

Table XII shows the results of leaching with HCl followed by HNO_3 leaching.

Table XII

HCl and HNO_3 Leaching

	Per Cent Ash
A. Head, 65-Mesh Glacier Anthracite	4.18
B. 65-Mesh Coal Treated 4 Hrs. 2N HCl	2.19
C. "B" ground to 200 mesh and treated with 2N HCl for 4 Hrs. at 100° C.	2.23
D. "C" treated with 5 times its weight of 15-per-cent HNO_3 for 1 hr. at 100° C.	1.87

It was shown that nitric acid has appreciable effects in de-ashing, and was better than HCl alone. It was, of course, not possible to reduce the ash content to the desired value of less than 0.5 per cent by the foregoing type of leaching. HCl was preferred as it was about one-half of the cost of HNO_3.

In general, the chemical treatment of coal may be classified as:

(1) Dissolution of the coal with organic solvents and removal of the coal substances from the ash-forming impurities by some form of filtration or precipitation.

(2) Dissolution of the impurities and filtration of the de-ashed coal from the spent leach acid. This procedure was considered as better suited to the Glacier anthracite, although bituminous and lower-rank coals might respond well to solvation processes.

(g) Magnetic Sepatation of Impurities. According to the literature on this subject, there are insufficient differences in the magnetic susceptibilities of the coal substances and their disseminated mineral impurities to reduce the ash constituents to any great practical extent.[20] The Glacier coal contained 0.4 per cent of iron, which could be reduced to 0.16 per cent by direct acid treatment, to 0.12 per cent by sink-and-float treatment, and to about 0.04 per cent by combination treatment. However, it was decided to make a test run using the laboratory "Ding's Magnetic Separator." Minus twenty-mesh Glacier coal of 4.18-per-cent ash was twice passed over the rotating rolls of this machine with a yield of 83 per cent of

cleaned coal, which had an ash value of 3.41 per cent, indicating that 18.4 per cent of the total ash was removable by this method. The cleaned coal was groundto minus 100 mesh and treated with 2N HCl, which resulted in a product having an ash value of 1.58 per cent.

10. Electrical Resistivity of Glacier Electrode Carbon

(a) Determination of Electrical Resistivity. The resistance of a sample of carbon is considered as the sum of the electrical resistance of the carbon substances plus the contact resistance of the particles. Values of resistivity of coke and carbon, reported in the literature, have been difficult to correlate in view of the fact that the contact resistance of the samples varied greatly with the test conditions; pressure on the samples, size of particles, design of test cell, presence of moisture and time of application of pressure, all variables, which must be standardized for a suitable test procedure.

Specific resistance is a measure of the electrical resistance of a material in terms of resistance per unit length per unit of area. In this investigation, the English units, "ohms per inch per square inch" abbreviated for convenience to "ohms/in.^{3}," have been used.

$$\text{Specific Resistivity, } R = \frac{E}{IL} A, \text{ or } R = r \frac{A}{L}$$

Where: A = Cross-sectional area of increment measured, sq. in.

R = Specific resistivity, ohms/in/in.^{2}

L = Length of increment, in.

r = Measured resistance, ohms

E = Voltage drop across specimen, volts

I = Current, amperes

Typical specific resistivity values for various electrode and cell-lining materials used by the aluminum industry are listed below:

	Ohms/in/in^2
Rotary Calcined Petroleum Coke, A	0.00192
Rotary Calcined Petroleum Coke, B	0.00202
Baked Carbon Electrode, A	0.00200
Baked Carbon Electrode, B	0.00201
Green Petroleum Coke, 900° C.	0.00250
Petroleum Coke Calcined at 1300° C.	0.00160
Pennsylvania Anthracite, Calcined at 1100° C.	0.00440
Mid-Continent Anthracite, Calcined at 1425° C.	0.00420
Calcined Lampblack	0.00780

The apparatus used for making such tests consisted of a Carver Press (or a Black Hawk 3 Ton jack, with dial guage and frame), an L. & N. Kelvin bridge ohmmeter of 0.01 x 10^{-4} to 0.1 ohms range, depth guage, feeler gauges, micrometer, and storage battery with leads. The test cell was made of mild steel, 2 inches long, lined with insulated material (micarta), drilled to a 0.25-inch bore. The electrical leads were screwed to the steel plunger head and base, which fitted into the bore of the cell for a distance of 0.25 inch. After making the test in the press, and while the pressure was still applied, the distance between the end of cell and the plunger head was measured with feeler guages to determine the length of the carbon sample.

The procedure of testing followed in this investigation was:

(1) A representative sample of the carbon was crushed in a clean mortar, the minus 20, plus 28-mesh fraction was then separated carefully with Tyler screens, and the sample stored in airtight, glass bottles until ready for test. Since samples which had been exposed to a moist atmosphere gave results that were as much as 3-per-cent too low, drying in an oven for 2 hours at 115° C. was adapted.

(2) 600 mg. of the prepared sample was placed in the test cell, which was closed at once.

(3) The loaded cell was then placed in the pressure frame (Carver Press) and the pressure increased by means of the jack to 70,000 p. s. i. The pressure was then released momentarily, and the sample allowed to expand and redistribute after which the test pressure was again applied and the resistance measured with a current of 20 amps., in the circuit, over a period of 10 minutes.

(4) The length of the sample was then determined, and the specific resistivity computed by application of the foregoing equation, as ohms/in./in.^{2}

The resistance of the system was frequently checked; and, unless the value obtained was less than 0.001 ohm, the terminals were cleaned and readjusted until a value equal to or less than 0.001 ohm was obtained. These adjustments were made with the leads connected to the two plungers and with a pressure of 70,000 p. s. i. applied to their surfaces. Duplicate determinations agreed within 3 per cent, with the machine in proper adjustment. Petroleum-coke samples of known resistivity were determined at frequent intervals as standardization checks. After about each 30 determinations with the resistivity cell, it was necessary to renew the micarta lining, which became pitted as a result of the repeated application of 70,000 p. s. i. pressure to the samples.

(b) Electrical Resistivity of Coal Coke and Carbon. As previously mentioned, the resistivity values of coke, determined by different investigators using various test procedures, have not been subject to satisfactory correlation. The U. S. Bureau of Mines,[25] has utilized a test procedure similar in all important respects with a method described in paragraph (a). It was reported that the resistivity of cokes prepared form the same coal decreased with increases in the carbonizing temperature. The average resistivity of these cokes made at 1100° C. was only 1/260,000th of that of the cokes made at 600° C. The quantity and quality of the volatile matter in the coke samples greatly affected the resistivity results, and it was stated that the logarithm of the resistance was a straight line function of the volatile matter remaining in the coke. It appeared that resistivities of about 0.002500 ohms/in.^{3} were approached as a limit. The lowest resistivity value actually determined was .00268 ohms/in.^{3} for coke prepared at 1100° C. from the Sewell Bed in West Virginia.

These investigations reported the resistivity values shown in Table XIII.

Table XIII

RESISTIVITY OF COAL COKE AND CARBONACEOUS MATERIALS

	Ohms/in/in^2
1100° C., Coke from Sewell Bed W. Va.	0.00295
1100° C., Coke from Sewell Bed W. Va.	0.00268
1100° C., Coke from Green River Bed Kentucky	0.00480
1100° C., Coke from Illinois	0.00638
Artificial Graphite, Acheson BB5	0.00106
Natural, Mexican Flake Graphite; 7% Ash	0.00134
Commercial, By-Product Coke, Pittsburgh, Pa.	0.00362
Sugar Char, 550° C/1 hour	0.00898

A theory, based on these resistivity determinations and work of Koppers and Jenkner,[26] who used coking temperatures up to 1200° C. on high-quality coking coals, and obtained resistivities down to 0.01590 ohms/in.^{3}, was proposed by Davis and Auvil in explanation of the decrease in resistivity with increasing plasticity and coking temperatures. Although our investigation of the resistivity of Glacier anthracite carbon does not necessarily confirm this early theory, it is quoted as showing the state of knowledge on this subject as late as 1935.[25,26]

> "There is an orientation of the carbon atoms into the graphite form during the plastic period (of coking); the extent of this orientation depends upon the plastic properties of the coal and the carbonizing conditions. The graphite molecules or minute crystals formed are practically dormant up to about 850° C. Above this temperature they increase enough in size to be indentified; their growth can be traced under the microscope with the use of polarized light."

Of further interest in connection with the determination of the resistivity values of coal carbon were the results reported on the resistivities of the petrographic constituents by McCabe in 1937.[27] It was found that moisture-free vitrain and clarain had resistivities greater than 300 megohm-centimeters (relatively nonconductors); fusain, however, had low resistivity. The Glacier product was a high-vitrain coal. In view of these theories the ultraclean Glacier anthracite was calcined and tested as shown in the following paragraphs.

(c) Calcination of Glacier Anthracite in Electric Resistance Furnaces. In order to make comparative tests, which would simulate, to some extent, commercial calcining processes, a new laboratory calcining technique was developed. Access of air to the sample undergoing laboratory calcination was prevented by the preparation and use of special double-wall graphite capsules of various sizes. These capsules with close-fitting caps were used in all of the calcination work. The sample was placed in a small graphite capsule, which in turn was placed in a larger graphite capsule; the annular space between them was then filled with powdered graphite, and the large cylinder covered with its graphite cap. The assembled unit was then put in a Lindberg Laboratory Resistance Furnace, equipped with an indicating pyrometer, for the calcining process. It was found that if air was allowed to contact the carbon during the calcination the sample was partly oxidized, the ash content greatly increased, and the resistivity results were not dependable.

Table XIV

RESISTIVITY RESULTS; ULTRACLEAN CALCINED GLACIER ANTHRACITE AND OTHER MATERIALS

Sample	Calcination		Ohms/in/in^2
	Time, Hr.	Temp. °C.	
No. 2-32; 36.6% Yield; 0.45% Ash	6	1200-1300	0.00304
No. 2-32; 36.6% Yield; 0.45% Ash	4	1200-1300	0.00366
No. 2-32; 36.6% Yield; 0.45% Ash	4	1200-1300	0.00351
No. 2-32; 36.6% Yield; 0.45% Ash	4	1200-1300	0.00394
Calcined Petroleum Coke (Run 1)		Commercial	0.00191
Calcined Petroleum Coke (Run 2)		Commercial	0.00186
Acheson's Flake Graphite		Commercial	0.00205

Table XIV (Cont'd)

Sample	Calcination Time, Hr.	Calcination Temp. °C.	Ohms/in/in^2
90% No. 2-32; 10% Heavy Fuel Oil	4	1200-1300	0.00377
80% No. 2-32; 20% Heavy Fuel Oil	4	1200-1300	0.00329
70% No. 2-32; 30% Lump Rosin	4	1100	0.00397
80% No. 2-32; 20% Sulfur	4	1100	0.00462
60% No. 2-32; 40% Heavy Fuel Oil	4	1100	0.00385
50% No. 2-32; 50% Heavy Fuel Oil	4	1100	0.00407
Calcined Wood. Char.	-	---	0.00995
50% No. 2-32; 50% Raw Pet. Coke	4	1100	0.00337

It is of note from the data in Table XIV that: (1) Calcination of the ultraclean Glacier anthracite for periods up to 4 hours at a maximum temperature of 1300° C. did not produce carbon having a resistivity value equal to that of calcined petroleum coke, (0.00186 ohms/in.^{3}); (2) addition of various organic materials to the anthracite prior to calcination did not appreciably depress resistivity values, but in most of the tests caused increases in the resistivities; (3) the deficient coking properties of the purified Glacier anthracite were apparently responsible for the high resistivity values obtained. It was desired that a more basic understanding of the role of hydrocarbon materials in promoting improved resistivities be developed. Of particular interest was theory applicable to the attainment of resistivity values in the range 0.00160-0.00191 ohms/in.^{3} found for calcined petroleum coke.

(d) Resistivity of Petroleum Coke. It was known that green petroleum coke, direct from the coking stills, would have resistivity values of 0.00250, or, frequently, much higher. After calcination for periods up to 24 hours at temperatures in the range 1050 to 1300° C., the resistivities become 0.00160 to 0.00200 ohms/in.^{3} In addition to this desirable improvement in the resistivity of the coke, calcination has been necessary to increase the density, strength, and molding and extrusion characteristics of the electrode carbon. It has been stated that the resistivity of carbon electrodes varies inversely with the elemental carbon content, directly with the percentage of volatiles, and inversely as the apparent and real densities. It was, therefore, obvious that the calcination step in preparing electrode carbon was of great importance as it affected all three of these factors.

The readiness with which a given petroleum hydrocarbon forms coke depends to a great extent on its position in the following series, which shows the change of one type of compound to another down the list, ultimately arriving at the carboids:

Paraffins
Olefins
Aromatics with side chains
Condensed ring systems
Asphaltenes
Carboids

The final product, petroleum coke, consisting of essentially the carboid materials, may be defined as the solid, infusible residue produced by the pyrolysis of petroleum under conditions such that the residue passes through a plastic stage before becoming infusible. X-ray analysis of petroleum coke has failed to show any special allotropic form of amorphous carbon. Such analysis has, however, shown that all forms of amorphous carbon and coal coke gave interference figures similar to those of graphite. Cathode-ray diffraction studies and electron-microscope examinations have shown petroleum coke to consist of minute, graphitic

crystallites surrounded by organic compounds of high molecular weight.[28] It has been considered by some investigators that such crystallites are not true graphite but are mesomorphous transition products between the parent carbonaceous material and true graphite. The X-ray examinations are interpreted as showing substances composed of hexagon lattice planes of carbon atoms but spaced farther apart than in graphite and not oriented with respect to one another.[28] In wood char produced at temperatures below 400° C.[30] and carbon black,[29] these graphitic crystallites have been observed.

The physical-chemical theories applicable to the formation of these crystallites may be summarized as follows:

> All cokes, including petroleum coke, are essentially disperse systems composed of minute crystallites embedded in a matrix of highly condensed aromatic compounds. The crystallites consist of either graphite or closely related substances. Such crystallites have been reported in asphalt. As carbonization proceeds the crystallites grow at the expense of the matrix, which also loses volatile matter and changes in character. The hydrogen content of the system naturally decreases as the temperature rises. Above 1100° C the hydrocarbon matrix has practically disappeared, but the crystallites continue to grow at higher temperatures, and conversion to massive graphite is not complete below about 2500° C. Petroleum coke thus forms part of a continuous series of disperse systems with asphalt at one end and graphite at the other. It comprises those members of the series which, on the one hand, do not soften on heating and on the other, are poor conductors of electricity compared with graphite.[31]

It was believed that the properties of the disperse system depended chiefly on the properties of the continuous phase or matrix. For petroleum coke the matrix was an infusible solid consisting of two types of materials: (1) trichloroethylene soluble asphaltenes, and (2) carboids insoluble in trichloroethylene. On further heating, it was claimed asphaltenes decomposed into carboids and volatile matter without fusion. Normal petroleum asphalt contained resins, oily constituents, and asphaltenes, which would form a matrix that fused at temperatures below the decomposition temperature of such a matrix. It was considered that the essential differences between petroleum coke and asphalt were: (1) The carboid content of petroleum coke increased on calcining and pyrolysis, without melting; and (2) asphalt always was melted before the heat of pyrolysis-produced carboids. In either case, the products produced at calcining temperatures above 1100° C. were claimed to contain essentially no matrix material; their important properties were believed to depend on the size of the crystallites produced. In this phase of the Glacier anthracite investigation, no extensive use of petroleum asphalt as a matrix was made because of the lack of resistivity improvement accomplished with the asphaltic substances in heavy fuel oil with calcining temperatures below 1400° C. In further studies, the use of asphalt pitch as a matrix in calcining at temperatures up to 2200° C. might prove of considerable interest. In our investigation, commercial, calcined petroleum coke ground to minus 200 mesh and examined with an RCA, Model EMU Electron Microscope at a magnification of 10,000 diameters, showed the carbon particles to be exceedingly small and well dispersed, but crystallinity was not definitely observed. X-ray diffraction studies of the same sample of petroleum coke were made and compared with similar studies of the uncalcined, ultraclean Glacier coal and this coal after calcination at 1800° C. with an equal weight of coal tar pitch. The results showed the calcined Glacier carbon to be more crystalline than the calcined petroleum coke or the uncalcined, ultraclean anthracite. From these preliminary investigations, it was evident that both the degree of dispersion and extent of crystallite formation were of importance in the processing of the Glacier anthracite to have resistivity values in the 0.00160-0.00191 ohms/in.^{3}, range of calcined petroleum coke. In the following sections the data cover the work completed in which the ultraclean Glacier coal was calcined with different quantities and kinds of matrix materials at temperatures in excess of 1400° C.

(e) Calcination of Glacier Anthracite in Electric Induction Furnace at Temperatures in Excess of 1400° C. The data listed in Table XV include the results of a variety of experiments which were made to answer the questions:

(1) By what means could ultraclean Glacier anthracite be treated to have a resistivity equal to calcined petroleum coke, 0.00160 to 0.00191 ohms/in.^{3}?

(2) Type and quantity of matrix necessary.

(3) Time and temperature necessary for proper calcination.

Since the answers to these questions were unknown, and it was desired to explore several such variables, small-scale, laboratory evaluation tests were preferred to the construction and operation of a pilot plant at greatly increased labor and material costs.

Table XV

RESISTIVITY RESULTS; EXPERIMENTS WITH THE HIGH-FREQUENCY INDUCTION FURNACE

(High-Frequency Ajax 10 kw. Laboratory Furnace 40,000 cycle/sec.)

Sample No.	Composition		Time	Temp. °C.*	Ohms/in/in^2
XX	100% Glacier 2-32	I	2 Hours	1700	0.00348
XXI	100% Glacier 2-32	I	1/2 Hours	1500	0.00550
XXIV	69.5% Glacier 2-32, 13.5% Hard Pitch; 17% Soft Pitch	I	4 Hours	1700	0.00220
XXV	100% Glacier 2-32	I	15 Min.	1800	0.00378
XXVb	100% Glacier 2-32	I	40 Min.	1800	0.00308
XXVI	69.5% Glacier 2-32, 13.5% Hard Pitch, 17% Soft Pitch	I	20 Min.	1800	0.00250
XXVII	80.0% Glacier 2-32; 20% Fuel Oil	I	30 Min.	1700	0.00462
XVIII	80.0% Glacier 2-32; 20% Soft Pitch	I	30 Min.	1600	0.00315
XXIX	80.0% Glacier 2-32; 20% Hard Pitch	I	60 Min.	1750	0.00330
XXX	60% Glacier 2-32; 40% Soft Pitch	I	10 Min.	1800	0.00174
XXXI	100% Soft Pitch Coke	I	10 Min.	1800	0.00228
XXXII	60% Glacier 2-32; 40% Soft Pitch	R	6 Hours	1100	0.00412
XXXIII	30% Glacier 2-32; 70% Soft Pitch	R	6 Hours	1100	0.00346
XXXIV	70% Hard Pitch; 30% Glacier 2-32	R	6 Hours	1100	0.00307
XXXV	50% Glacier 2-32; 50% Soft Pitch	I	30 Min.	1800	0.00174

* By L. & N. optical pyrometer readings on graphite crucible.

I = Calcined in High-Frequency Induction Furnace.

R = Electric Resistance Furnace.

The data in Table XV are reported in the order in which the experiments were performed. Four runs were made with the ultraclean Glacier anthracite 2-32 alone (XX - I, V and Vb), calcined at temperatures of 1500 to 1800° C. for periods varying from 1/4 to 2 hours. In no case was resistivity of less than 0.00308 ohms/in.^{3} accomplished. With sample XXIV, a baked mixture of hard and soft coal tar pitches with 69.5 per cent of the ultraclean Glacier coal, the improved value of 0.00220 ohms/in.^{3} was obtained, indicating the direction in which further work should be done. Runs XXVI - XXIX, inclusive, with 20 to 30 per cent of pitch were unfavorable. When, in sample XXX, the pitch was increased to 40 per cent and the mixture calcined ten minutes at 1800° C. for the first time a low resistivity value, 0.00174 ohms/in.^{3}, was obtained. One-hundred-per-cent soft pitch, when calcined at 1800° C. for 10 minutes, did not result in a very low resistivity product, only 0.00228 ohms/in.^{3}

Runs XXXII to XXXIV were then made in the resistance furnace at 1100° C. for 6 hours. Since the resistivities were 0.00307 or higher, even for blends containing up to 70% of soft pitch, it was concluded that, to prepare Glacier carbon having a specific resistivity of 0.00200 or less, a sufficient amount of a volatile matrix, such as coal tar pitch, was necessary and that the amount of pitch was critical in the 35-45 per-cent range. Furthermore, if the calcination was carried out at the high temperature level of 1800° C., which is substantially below the graphitisation temperature of 2400° C., the low-resistivity carbon could be made in less than ten minutes. Data of this type had not been noted in the literature, and the results reported above were considered of sufficient novelty that they have been the subject of an application for a U. S. patent. It should be clear, however, that the results reported here were obtained on a specific type of anthracite coal; such processes to produce low resistivity may not be necessary for high-ranking, coking-grade coals or coals from other fields.

(f) Calcination of Glacier Anthracite in the Electric Arc Furnace. In section (e) it was reported that the factors necessary for preparing carbon of low resistivity from the Glacier coal were:

(1) Matrix, 40% soft pitch

(2) Temperature of Calcination, 1800° C.

(3) Time, ten minutes or less

This was considered as only one set of conditions under which electrode carbon could be derived from the de-ashed Glacier coal. Before designing and operating a pilot plant on which to base reliable cost data, the following factors should be evaluated in the laboratory:

(1) Other types of hydrocarbon matrix

(2) Possibilities for condensing the volatiles from the calcination of the soft pitch

(3) Re-cycling condensed volatiles as a matrix

Four runs were made for durations of 112 to 120 hours each, in the normal calcination temperature range of 1100-1200° C. The object of this series of tests (XXXVI to XXXVIII) was to determine if the long periods of calcination would promote the growth of the crystallites and cause consequent low resistivity. The results were negative, and resistivities of less than 0.00380 ohms/in.^{3} were not obtained even when 40 per cent of soft pitch matrix was used.

The rapidity with which low resistivity was accomplished in the high frequency induction furnace suggested the possibility that the orientation of the carbon atoms in forming the graphic crystallites or causing some form of orientation resulting in low resistivity, might be due to the effects of the high-frequency alternating field. The Ajax Converter used in the tests reported in Table XV had an output of 10 kw. at 40,000 cycles per second.

Table XVI

RESISTIVITY RESULTS
ELECTRIC ARC FURNACE (1400-1850° C.)
GLOBAR RESISTENCE FURNACE (1100-1200° C.)

Sample No.	Composition	Time	Temp. °C.	Ohms/in/in^2
XXXVI	100% Glacier 2-32	112 Hours	1100-1200	0.00482
XXXVII	60% Glacier 2-32; 40% Soft Pitch	112 Hours	1100-1200	0.00408
XXXVIa	100% Glacier 2-32	120 Hours	1100-1200	0.00447
XXXVIIa	60% Glacier 2-32; 40% Soft Pitch	120 Hours	1100-1200	0.00380
XXXVIII	50% Glacier 2-32; 50% Soft Pitch	30 Min.	1400-1700	0.00300
XXXIX	50% Glacier 2-32; 50% Soft Pitch	50 Min.	1750-1800	0.00213
XXXXIV	40% Glacier 2-32; 60% Soft Pitch	1 Hour	1800-1850	0.00158

Tests XXXVIII, XXXIX, and XXXXIV were therefore made in a carbon arc furnace, the sample capsule being placed directly between the two, 1 1/2-inch graphite arc electrodes, which were fed with a current of about 300 amps., at 40 volts. The arc furnace was selected as a means of readily attaining calcining temperatures in the 1800° C. range, without a high-frequency alternating field. The results obtained, while not definitely conclusive because of the possible unreliability of the temperature determinations, have shown that the arc furnace was considerably slower in calcining to a low-resistivity value; in one hour a value of 0.00158 was obtained. With the induction furnace the value of 0.00174 ohms/in.^{3} was reached in less than 10 minutes. Further research with a converter capable of producing frequencies over a wide band, might prove fruitful.

11. Glacier Electrode Carbon, Compared with Calcined Petroleum Coke

A summary of the properties of a commercial, calcined Petroleum Coke, compared with corresponding properties of calcined Glacier carbon, is shown in Table XVII. The Glacier calcined carbon represented the following approximate yields based on 100-per-cent, air-dry, raw coal.

	Per cent by Weight
Heavy-Density Float	36.6
Loss on HCl Treatment	5.0
Volatiles and Moisture on Floated Coal	7.5
Yield on Calcining: 40% Soft Pitch, treated 60% Float No. 2-32	73.8

The estimated net yield of Glacier carbon after calcining was 32.16 per cent of the air-dry, raw coal. Approximately 50 per cent of the soft pitch used as a matrix was lost as volatiles during calcination; in commercial practice much of the volatile material could be condensed and re-used. The economics of the process will, of course, depend on the demands of the aluminum industry as to the exact quality of the carbon required. If, as has

been assumed, quality equivalent to petroleum coke is specified, and the raw Glacier coal was made available at $9.00 per ton, it has been estimated that the cost of the calcined Glacier carbon would be $43.55 per ton, with yields as mentioned above. Reliable cost estimates could best be made from pilot-plant data. The cost estimates given here are based only on small-scale laboratory tests and should be considered only as rough approximations. With the value of petroleum coke at $39.00 per ton, it is evident that the possibilities for profit which may accrue from the substitution of Glacier electrode carbon for petroleum coke will depend on further economies in the use of matrix material or other improvements in process variables which could be developed. It is believed, however, that the unfavorable economics of the process should not prevent further research directed toward decreasing costs of the process.

Table XVII

SUMMARY OF THE PROPERTIES OF CALCINED PETROLEUM COKE AND CALCINED GLACIER CARBON

Properties	Petroleum Coke	Calcined Glacier Carbon
Specific Resistivity	0.00186-0.00191	0.00174
Per-cent Composition: (Air-Dry Basis)		
Total Ash	0.38	0.44
Moisture	0.09	0.08
Sulphur	1.06	0.79
Fe	.030	.030
Ca	.040	.040
Na	.040	.010
(Ca + Na)	(.080)	(.050)
Si	.040	.050
K	.005-	.005-
Al	.012	.012
Ba	.001	.001
Cr	.005	--
Co	.001	.0005
Cu	.002	.002
Pb	.006	.002
Mg	.006-	.015
Mn	.001-	.001
Mo	.001-	.001-
Ni	.050-	.005-
Ag	.0005	.0005
Sr	.0005	.0005
Sn	.002-	.002-
Ti	.0004	.002-
Va	.040	.001
Real Density	2.06	Not determined

It was concluded that the calcined Glacier carbon was equivalent in all important respects, to the calcined petroleum coke. Of particular note was the low nickel and vanadium contents of the Glacier carbon as compared with the petroleum coke. The Glacier carbon was found to be very hard and strong when ground in a mortar; and, from its appearance and character, it was concluded there should be no greater difficulty in producing extruded, baked electrodes of satisfactory strength and uniformity than that encountered in conventional procedures.

12. Conclusions and Recommendations

Conclusions:

(a) The investigation has shown that, from the technical standpoint at least, electrode carbon equivalent to calcined petroleum coke can be prepared from the anthracite coal of low-ash value obtainable from the Glacier Field, Whatcom County, Washington.

(b) For the first time, ultraclean, low-resistivity carbon was made from Washington anthracite coal.

(c) A study of coal beneficiation procedures has been made with particular regard to the characteristics of the Glacier anthracite, and new laboratory techniques were developed for the evaluation of coal as a source of electrode carbon.

(d) It was considered that the results obtained were sufficiently favorable to warrant thorough investigations of other, lower-ranking coals of the state as suitable sources of electrode carbon. This was particularly desirable in view of the tremendous quantity of such coals in the state as compared with the estimates of Glacier coal resources.

Recommendations:

In view of the favorable possibilities for producing low-ash electrode carbon from Glacier anthracite, and the properties of this coal, which indicate its usefulness in the electro-chemical industry, it is recommended that further efforts should be made to evaluate the quantity and quality of this important state resource.

SUMMARY

A review of the available literature covering the processing of coal resources for the production of electrode carbon for the aluminum industry has emphasized the importance and desirability for more fundamental and practical information in this field. Much new information was derived as a result of extensive experimental work; and a process was developed in the laboratory whereby, for the first time, electrode carbon, which is equivalent to the calcined petroleum coke commercially used by the aluminum industry, was prepared from low-ash, anthracite coal from the Glacier Field, Whatcom County, Washington. Further specific evaluation of this anthracite field, with respect to its magnitude and quality of its coal, by competent mining engineers and geologists was considered an essential basis for possible future, pilot-plant construction and operation with the process developed.

The studies of coal-beneficiation procedures and the new laboratory techniques, which were developed for the evaluation of coal as a source of electrode carbon, should be of particular value in future investigations of lower-ranking coals of the state as sources of ultraclean, low-resistivity carbon.

It was found that to prepare Glacier anthracite carbon equivalent to calcined petroleum coke, three major operations were necessary (See Figure 1):

(a) Sink-and-float beneficiation, or other methods of cleaning, to reduce the ash content by approximately 50 per cent.

(b) Treatment of the float-coal with hydrochloric acid to further reduce the ash to a value of 0.50 per cent or less.

(c) Calcination of the ultraclean coal in the presence of suitable matrix material, at temperatures in the 1400 to 2000° C. range, for production of carbon having specific resistivity of less than 0.00200 ohms/in.^{3}

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THE PRODUCTION OF ELECTROLYTIC MANGANESE DIOXIDE

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THE PRODUCTION OF ELECTROLYTIC BATTERY-ACTIVE MANGANESE DIOXIDE

INTRODUCTION

Because of the serious deficiency of manganese ore on the North American continent, it was believed that a research project to investigate the occurrence and treatment of ores in the Northwest, especially in the state of Washington, was justified. Therefore, an agreement between the Division of Industrial Research, State College of Washington, and the Bonneville Power Administration (Contract Ibp-4226, Supplemental Agreement No. 17) was entered into, certain funds being provided by the Bonneville Power Administration and matched by the Division of Industrial Research, State College of Washington.

Anticipation that any manganese ores available would be too low in grade for direct metallurgical use brought about the decision to investigate the production of manganese dioxide of battery grade by electrolysis. This view was strengthened by the fact that when an ore requires treatment by chemical dissolution, the final product should be as valuable as possible.

As the work progressed, it became more and more evident that manganese ores occurring in the Northwest, outside of the Phillipsburg, Montana, District, occur in scanty deposits, which could not be depended upon to furnish a steady feed to even a small plant. Investigation of the hydrous silicate manganese minerals of the Olympic Peninsula, Washington, both by direct examination and by conversations and correspondence with others, led to the disappointing conclusion that there are no proved large deposits of manganese minerals available in that district. During the first week of June, 1951, the writer, accompanied by Mr. W. J. Wendt [1] and Mr. W. A. G. Bennett,[2] made an inspection of several manganese claims on Steele Creek, South Fork of the Skokomish River, and one claim on the Dosewallips River. All of these prospects are discussed by Stephen H. Greene[3]. In the opinion of the writer and the others mentioned, it is doubtful if there is sufficient manganese in any of the claims visited to warrant any hopes that commercial quantities exist.

Two reputed sources of manganese ore near Medford, Oregon, were visited by the writer, accompanied by Mr. J. G. McCallum,[4] in October, 1950. One was a deposit on Lake Creek, which had been worked during World War I.

1/ Junior Chemist, Mining Experiment Station, Division of Industrial Research, State College of Washington, Pullman, Washington.

2/ Geologist, Department of Conservation and Development, Division of Mines and Geology, Transportation Building, Olympia, Washington.

3/ Report of Investigations No. 7. "Manganese Deposits of the Olympic Peninsula, Washington" by Stephen H. Greene, Department of Commerce and Development, Division of Mines and Mining, Olympia, Washington.

4/ Industrial Engineer, United States Department of the Interior, Bonneville Power Administration, Portland, Oregon.

It had been originally a very small deposit and was completely worked out. A shot fired at the end of the thirty-foot drift revealed only barren rock. Manganese minerals were supposed to occur as nodules in volcanic tuff on Evans Creek. Investigation of the prospect revealed fragments of basalt embedded in the tuff, but no manganese minerals were discovered.

Initial work on roasting and leaching was performed on a five-hundred pound sample of Olympic Peninsula bementite ore sent by Mr. E. F. McTarnahan.[5/]

After it became evident, however, that the Olympic Peninsula could not be depended upon to furnish a steady supply of ore of even quality, it was decided to turn to other sources. A shipment of two tons of Tasmanian manganese ore was procured from the Pacific Northwest Alloys Corporation, and the latter phases of the work were done using this ore as a source of manganese sulfate solution.

During progress of the work it became evident that the major problem was the determination of conditions of electrolysis necessary for the production of the desired battery-active manganese dioxide, as the extraction of the manganese from the ore presented no great difficulties.

MANGANESE MINERALS

The naturally occurring compounds of manganese are many and complex; and, since ores of manganese usually consist of mixtures of compounds grading into each other, mineralogical examination is made extremely difficult. A substantially complete list of the oxide minerals, identified by X-ray diffraction supplemented by chemical analysis was published by Fleisher and Richmond.[6/] They are listed on page 3.

The carbonate of manganese, rhodochrosite, $MnCO_3$, is a fairly common source of manganese. It usually occurs with more or less calcium and grades into manganocalcite, $XMnCO_3 \cdot CaCO_3$. Since the presence of lime is undesirable in any process involving leaching with sulfuric acid, the use of carbonate ore was avoided, although it has the desirable property of yielding its manganese to sulphuric acid leaching without prior reduction roasting.

The silicate minerals include the following, listed by Dana:[7/]

Rhodonite	$MnSiO_3$
Bementite	$H_6Mn_5(SiO_4)_4$
Neotocite	$MnSiO_3 \cdot XH_2O$

Many other hydrous silicates are listed, but the above are the most impo ant for consideration in this report.

5/ President, Rotary Mills, Inc., 3330 Fuhrman Avenue, Seattle, Washington.

6/ Fleisher, Michael, and Richmond, Wallace E. "The Manganese Oxide Minerals: A Preliminary Report" Economic Geology, 38:398-98.

7/ Dana's Textbook of Mineralogy, Third Edition: John Wiley and Sons, Inc., New York.

MANGANESE OXIDE MINERALS

(After Fleischer and Richmond)

Bixbyite $(Mn \cdot Fe)_2O_3$

Braunite $3(Mn \cdot Fe)_2O_3 \cdot MnSiO_3$

Cesarolite $PbMn_3O_7 \cdot H_2O$ (rare)

Chalcophanite $(MnZn)Mn_2O_5 \cdot H_2O$ (rare)

Coronadite PbR_8O_{16} (?) R=Mn^{IV} chiefly, also Mn^{II}, Cu, Zn

Crednerite $CuMn_2O_4$ (rare)

Cryptomelane KR_8O_{16} (?) R=Mn^{IV} chiefly, also Mn^{II} Co, Zn

Galaxite $(Mn^{II}, Fe^{II})(AlFe^{III})_2O_4$ (rare)

Hausmannite $MnMn_2O_4$

Hetaerolite $ZnMn_2O_4$

Hollandite BaR_8O_{16} (?) R=Mn^{IV} chiefly, also Fe^{III}, Mn^{II}, Ce

Jacobsite $(Mn^{II}, Fe^{II}, Mg)(Mn^{III}, Fe^{III})_2O_4$

Lithiophorite $Li_2(Mn^{II},Co,Ni)_2Al_8Mn^{IV}{}_{10}O_{35} \cdot 14H_2O$ (?)

Manganite $MnO \cdot (OH) = Mn_2O_3 \cdot H_2O$

Manganosite MnO (rare)

Polianite = Pyrolusite. The name polianite should be dropped.

Psilamelane $BaR_9O_{18} \cdot 2H_2O$ (?) R = Mn^{IV} chiefly, also Mn^{II}, Co

Pyrochroite $Mn(OH)_2$ (rare)

Pyrolusite MnO_2

Quenselite $Pb_2Mn_2O_5 \cdot H_2O$ (rare)

Ramsdellite MnO_2 (dimorph of pyrolusite)

Rancieite $(Ca,Mn^{II})Mn^{IV}{}_4O_9 \cdot 3H_2O$ (?)

Sitaparite = Bixbyite. The name sitaparite should be dropped.

LIXIVIATION OF MANGANESE ORES

The method chosen for the dissolution of manganese from its ores will depend on several considerations. These are:

(a) The nature of the ore. Manganese in the bivalent form, except when combined with silica as rhodonite, is soluble in sulfuric acid without any prior treatment such as roasting. The carbonate, rhodochrosite, is an example of this. In the mineral rhodonite it seems that the chemical stability of the silicate prevents the dissolution of the manganese even though it is in the bivalent state. Mixed oxides, such as hausmanite, Mn_3O_4, or manganite, $Mn_2O_3 \cdot H_2O$, should yield that fraction of the manganese which is in the bivalent state to sulfuric acid leaching. Bivalent manganese compounds are also soluble in ammonium hydroxide-ammonium salt mixtures, as shown by Zapffe[8] and Dean.[9] Ores which contain manganese in higher states of oxidation than the bivalent require reduction either prior to the leaching step or a lixiviant which reduces the ore during leaching. This is the usual situation, as few manganese ores contain only bivalent manganese.

Sulfur dioxide is a satisfactory lixiviant for manganese ores containing the higher oxides. Results on the use of this solvent are reported by Davis.[10] However, its use is not suitable for the process under consideration for two reasons. They are: (1) The process of producing manganese dioxide by electrolysis regenerates sulfuric acid, which must be returned as spent electrolyte to the leach, since the depletion of the electrolyte in the cells is far from complete. If sulfurous acid were used as a lixiviant, the constant generation of sulfate in the system would make operation impossible unless the spent electrolyte were disposed of. If the electrolysis could be carried out to completely deposit the manganese, sulfuric acid could be recovered from the spent electrolyte, and sulfurous acid could be used as a lixiviant. This, however, is not practical, as actually only about half of the manganese is removed during the electrolysis. (2) When the higher oxides of manganese are dissolved with sulfurous acid the formation of manganese dithionate cannot be avoided. Latimer and Hildebrand[11] give the reaction as follows:

$$MnO_2 + 2H_2SO_3 = MnS_2O_6 + 2H_2O.$$

It has been observed that when a manganese solution containing dithionate is electrolysed sulfur precipitates in the cell and hydrogen sulfide is generated, both of which reactions are undesirable. It has also been shown

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8/ Zapffe, Carl, "Leaching Manganese from Silicous Iron Ores of Minnesota," Eng. and Min. Jour. Vol. 127 and 128, June 29, 1929 and July 6, 1929, pp. 1020-1041 and pp. 14-19.

9/ Dean, Reginald S. "Manganese Extraction by Carbamate Solutions and the Chemistry of New Manganese - Ammonia Complexes." Min. Eng. Jan., 1952, pp. 55-60.

10/ Davis, C. W. U. S. Bureau of Mines R. I. 3024.

11/ "Reference Book of Inorganic Chemistry," The Macmillan Co., New York (1933) p. 203.

that a process of baking and roasting manganese ores with sulfuric acid will produce water-soluble manganese sulfate. Parkman[12] tested this process on the high silica ores of the Olympic Peninsula. The process consists of mixing the ground ore with sufficient sulfuric acid (50° Be) to sulfate all the bases present, including the manganese, and baking at 200°C. in order to promote as complete sulfating as possible. This is followed by roasting at a temperature sufficiently high to decompose the ferric sulfate to insoluble ferric oxide and the aluminum sulfate to aluminum oxide but leave the manganese sulfate undecomposed. Thus, a water leach will extract the water soluble manganese sulfate and leave iron, alumina, lime and other gangue materials in the residue. The chemistry involved is probably according to the following reaction:

$$2MnO_2 + 2H_2SO_4 = 2MnSO_4 + 2H_2O + O_2.$$

The formation of intermediate peroxyacids is probably involved. It will be noted that chemical reduction of the tetravalent to bivalent manganese takes place. This method of attacking manganese ores, however, is unsuited to a cyclic process such as is under consideration because the dilute acid (100 grams per liter) returning from the electrolytic cells would have to be concentrated by a costly evaporation step before it could be used in furnace sulfating.

Other methods of extracting manganese from ores in various states of oxidation make use of nitric acid.[13], [14] No investigation of nitric acid methods was attempted in this investigation because the nitrates are unsuited for electrolysis.

(b) The important consideration in choosing a method of extracting manganese from ores for electrolytic manganese dioxide, as well as for electrolytic manganese metal, is that the sulfuric acid is regenerated. As mentioned in the foregoing discussion of lixiviation, sulfurous acid is not applicable because it generates new sulfate, leaving no means of recirculating the spent electrolyte. The sulfuric acid baking process is not practical because it would involve the evaporation of large quantities of water. For the above reasons, the method making use of the reducing roast of the ore prior to leaching was chosen for this research. This reducing roast has been thoroughly investigated by the staff of the U.S. Bureau of Mines working on the electrolytic manganese metal process.[15] The bulletin cited sums up

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12/ "The Development of a Sulfuric Acid Baking--Roasting and Leaching Process for the Extraction of Manganese from the High-Silica Ores of the Olympic Peninsula of Washington" by H.C. Parkman and Charles Durway: State College of Washington, State Electrometallurgical Research Laboratories, Pullman. Bulletin M, July 25, 1936.

13/ Dean, R. S., Fox, A. L., Back, A. E. "Nitrogen Dioxide Process for the Recovery of Manganese from Ores." U.S. Bureau of Mines R.I. 3626, March 1942.

14/ Nossen, E. S., "New Process Gives U.S. 100 Year Supply of Manganese." Chem. and Eng. News, Vol 29, p. 287, Jan. 22, 1951.

15/ "Operation of Electrolytic Manganese Pilot Plant, Boulder City, Nevada" U.S. Bureau of Mines Bulletin 463, 1946. By J. H. Jacobs, J. W. Hunter, W. H. Yarroll, P. E. Churchward and R. G. Knickerbocker.

the results of an enormous amount of work done on reduction roasting and leaching manganese ores. Briefly, the ore is roasted at about 600°C. in a reducing atmosphere produced by the presence of an excess of organic carbonaceous material. Oil is probably the most convenient reducing agent. Calcine roasted in this manner will give up its manganese readily to dilute sulfuric acid.

PURIFICATION OF LEACH SOLUTIONS

Purity of solutions is important if a battery-active manganese dioxide is to be obtained. However, extreme purity such as is required for the manganese metal process is not warranted. Shelton and others[16] first proposed the addition of ferrous iron to the leach solution followed by oxidation to precipitate ferric hydroxide which occludes and removes arsenic, antimony, and colloids. This was followed by the addition of sodium ethyl xanthate and potassium pentasol xanthate to precipitate cobalt and nickel and copper. Later the process was improved by E. S. Dean and others[17] by using barium sulfide or ammonium sulfide to precipitate the nickel, cobalt, and copper instead of the xanthates. The method of purification adopted for the work being reported was based on the above work.

ELECTROLYSIS

Little has been published on the electrolysis of manganous sulfate solutions for the production of manganese dioxide, although an enormous amount of literature has been published on the electrolysis of manganese metal. In this latter process the anodic deposition of manganese dioxide is avoided as much as possible. O. W. Storey and others[18] discussed the anode problem. They stated that lead anodes are undesirable because they produce a product highly contaminated with lead and recommend the use of graphite at low current density. They give the reaction as follows:

$$Mn^{++} + 2H_2O = MnO_2 + \tfrac{1}{2}O_2 + 2e \quad Eo = 1.35$$

also the electrolytic decomposition of water is given as:

$$H_2O = H_2 + \tfrac{1}{2}O_2 \qquad Eo = 1.70$$

They state that if the current density is too high, the cell voltage will exceed 1.70 volts and oxygen will be generated at the anode which promotes excessive corrosion of the graphite and a poorly conducting form of manganese dioxide results. At low current densities, however, a highly conducting variety of the dioxide results and graphite corrosion is greatly reduced. They used "hot" solutions but did not mention any figures for temperature. R.T.C.

16/ U.S. Bureau of Mines R.I. No. 3406 by S.M. Shelton and others and Eng. and Min. Jour. Vol. 137, 1936, p. 510 by J. Koster and S.M. Shelton.

17/ "Electrolytic Manganese and Its Alloys," U.S. Bureau of Mines R.I. 3681.

18/ "The Anode Problem in the Electrodeposition of Manganese Dioxide," O. W. Storey, Ernest Steinhoff and E.R. Hoff, Trans. Electrochem. Soc., Vol. 86, pp. 337-344, 1944.

Rasmussen[19] revealed the following Japanese practice: "The electrolytic cells were arranged in cascade. Present cathodes are perforated plates of pure lead and the anodes are lead containing 8 per cent antimony. Clean rhodochrosite ore from Hokkaido is reduced to minus 60 - mesh in a jaw crusher and rolls; a cyclone separator removes the extreme fines. Leaching with hot, 10 per cent sulfuric acid is done in tanks with mechanical agitation. The pulp settles for three hours in a lead-lined, cone-bottom tank, after which the clear solution is siphoned off and the thickened pulp filtered in a plate and frame press. Filter cake analyses 10 per cent manganese. The pregnant solution goes, without purifying, to the electrolytic cells; the electrolyte is straight manganese sulfate solution. The bus bars are between two rows of cells with the ends of the electrode bars merely resting on the bus bar and the other ends resting on insulators on the outside edge of each row of cells; manganese dioxide is stripped from the anodes every 144 hours, washed in water and dried. Present production is 9 tons per month."

Two samples of the Japanese product were obtained and analysed. They were found to contain 0.3 - 0.4 per cent lead. This is high, but lower than one would expect for material deposited on lead anodes.

There are several plants producing electrolytic manganese dioxide in the United States. Details of operation of these plants are not available; but, from sketchy information, the conclusion is drawn that graphite electrodes are used and that the cell electrolyte is held at a high temperature.

From the above, it will be understood that research on electrolysis of manganese dioxide was aided very little by published data. The problem, therefore, was attacked without predetermined ideas as to the optimum conditions of current density, electrolyte acidity and manganese content, temperature, and electrode materials.

ALLOTROPIC FORMS OF MANGANESE DIOXIDE

The depolarizing properties of battery-active manganese dioxide seem to depend primarily on the crystal form. The various forms of the dioxide are discussed by MacMurdie and Golovato.[20] They have come to the conclusion that the following forms exist:

(1) Well crystallized pyrolusite
(2) Gamma manganese dioxide, a poorly crystallized pyrolusite
(3) Ramsdellite
(4) Cryptomelane, a form containing essential potassium or sodium
(5) Delta, poorly crystallized cryptomelane

Of these, only the gamma form seems to give the desired high battery activity and the principal object of this research was to determine proper electrolysing conditions for the production of the gamma form.

19/ Rasmussen, R.T.C., "Memorandum for Record on Chuo Denki Kogyo Co., Ltds., Taguchi Factory, Jan. 15, 1947"--Private communication to writer.

20/ "Study of the Modifications of Manganese Dioxide" by Howard F. MacMurdie and Ester Golovato, Research Paper RP 1941, Jour. Res. Nat. Bureau of Standards, Vol. 41, Dec. 1948.

Though this process is a cyclic one, the natural sequence being roasting-leaching-purification-electrolysis, the following experimental part of this report considers each of these steps separately, since it is felt that the subject matter can be presented thus in a more orderly manner.

ROASTING

Preparation of Ore

The fineness of grind necessary for satisfactory reduction roasting of manganese ore depends upon the nature of the ore. That from the Three Kids mine in Nevada[21] can be satisfactorily roasted fairly coarse, minus 35-mesh, because of the natural porosity of the material. The above is an unusual case, however. It was determined that both types of ore used in this work, the Tasmanian Ore, as well as that from the Olympic Peninsula, Washington, had to be ground to at least minus 48-mesh, preferably to minus 65-mesh, in order to get satisfactory reduction of the manganese to the bivalent state and easy solubility of the manganese. The usual laboratory crushing, grinding and screening equipment, consisting of a jaw crusher, gyratory crusher, rolls, rod mill, and shaking screen was used in this work.

In plant practice it is suggested that dry grinding with air classification would be most satisfactory. Wet ball-mill grinding using hydraulic classification, as done in most ore mills, is undesirable because it would involve a troublesome filtration step and possibly a dryer before the ground ore entered the roaster.

As discussed in the introduction, the manganese in an ore must be reduced to the bivalent state to be soluble in dilute sulfuric acid. Coal, coke, gas, fuel oil, or any other organic carbonaceous material can be used. Sawdust was used as a reducing agent, with one exception, in all the roasting done in connection with this research. It was chosen because of its cheapness and availability in this region.

Preliminary work on the necessary ratio of manganese to sawdust and size of ore particles required was made in a Lindberg laboratory tube furnace. Two grams of ore were mixed with sawdust, placed in a nickel boat, and inserted in the furnace. The furnace tube was flushed with nitrogen to displace atmospheric oxygen and a slow stream of nitrogen flowed through the tube during heating and cooling. The furnace was brought up to 700°C., held at that temperature for one hour, then cooled. The reduced material was pulverized, agitated with an excess of ten per cent sulfuric acid at room temperature for one hour and allowed to stand overnight. It was then filtered and manganese determined on the filtrate and residue. The first series of tests used a commercial grade of pyrolusite, 85 per cent manganese dioxide. The results indicated that one part of sawdust by weight was necessary to reduce one part of manganese in the ore.

The above result was disproved in later work where a specially constructed manganese roaster was used, the sawdust requirement being considerably lower than indicated by these preliminary tests. The reason is

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21/ "Operation of Electrolytic Manganese Pilot Plant, Boulder City, Nevada" U.S. Bureau of Mines Bulletin 463.

undoubtedly due to the fact that when using the Lindberg tube furnace in an atmosphere of nitrogen, the volatile gases, consisting of alcohols, creosotes, and the like, were diluted with the nitrogen and their effectiveness as reducing agents largely wasted. In the laboratory roaster, described later, these volatiles remained trapped in the roasting drum thus preserving their effectiveness as reducing agents.

Particle Size

Tests were run on Olympic Peninsula ore from the Blue Ox and Handy claims in the Lake Crescent district to determine the influence of particle size on the effectiveness of roasting. In previous work with the tube furnace using commercial grade ore, (85 per cent manganese dioxide), it was found that a 1 : 1 ratio of sawdust to manganese would give satisfactory leaching results. The ore from the Blue Ox and Handy claims assayed 33.8 per cent total manganese and 10.4 per cent acid soluble manganese. Therefore, on a basis of 1 : 1 it would take 1 part of sawdust to 4 parts of ore. In the following tests (Table No. 1), however, sawdust was used amounting to 1 : 1 ratio to total manganese content of the ore (3 : 1 ore to sawdust).

TABLE I

Test No.	Grams Ore	Mesh	Grams Sawdust	Per cent of Manganese, Acid Soluble
1	2.0	- 10	0.67	13.8
2	2.0	- 35	0.67	60.3
3	2.0	- 48	0.67	69.0
4	2.0	- 65	0.67	70.9
5	2.0	- 65	0.67	82.4

Since the above tests were made to determine the necessary size reduction of the ore, the analysis for soluble manganese was made on the calcine without further reduction in size. (Ordinarily the calcine was ground through 150-mesh to determine acid soluble manganese.) It is to be noted that in Test No. 1 above, the 10-mesh ore gave only 13.8 per cent solubility of the manganese. This same ore, even when unroasted, showed 31 per cent solubility of the manganese when the material was ground through 150-mesh. This indicates the importance of fine grinding for maximum manganese extraction.

Laboratory Roaster

The next step was to design and construct a practical roaster large enough to furnish calcine for pilot scale leaches. A drum 18 inches in diameter and 14 inches long was constructed of 1/8-inch stainless steel. A 6-inch opening was cut at the axis on one side of the drum, and a 6-inch diameter stainless steel tube, 2 feet long was welded on coaxially. A similiar 6-inch tube was welded on the other side of the drum, but not communicating with the space inside of the drum. The two 6-inch tubes extending coaxially from the drum were supported by pairs of rollers on each end so that the drum could be rotated at four revolutions per minute by means of a one-quarter horsepower motor and speed reducer. The drum was placed in a

furnace with a removable arch and openings at each end to permit the 6-inch supporting stems to rotate freely. Heat was applied by two Denver Fire Clay Company propane burners, baffled to prevent the flame from playing directly on the stainless steel drum. The one 6-inch stem, left open and communicating with interior of the drum was fitted with a loose plug which was separately mounted and held stationary. A thermocouple was fitted through the axis of this plug and extended through the 6-inch stem into the drum. (See Fig. No. 1 for a drawing).

Operation of Manganese Roasting Furnace

The furnace arch was removed by means of a travelling crane, and the drum hoisted up out of the furnace by means of a fork with hooked prongs which fitted around the 6-inch stems of the drum. The drum was then upended by putting a cable hitch around the open stem and lifting with the crane. It was charged while in this position. The above sequence was reversed to place the drum back in the furnace. The plug with the thermocouple was then placed in the open stem and lined up so that the drum would turn freely--the open stem turning around the stationary plug. The propane burners were then started and the roasting procedure carried out, the rotation of the drum continuing during the whole roasting and cooling period. During the cooling period the thermocouple plug was removed and the open stem capped with a specially constructed cap, clamped on by means of set screws and sealed with fire-clay.

Since it is necessary to cool the calcine to 100°C. in a reducing atmosphere, it was found impossible to make more than one roast per 24 hours when the calcine was cooled in the furnace. To speed up the production of calcine a calcine cooling stand was constructed. This was done by mounting two sets of rollers with a motor and speed reducer, identical with those of the furnace, on the floor beside the furnace. After the roast in the furnace was completed, the open end of the drum-stem was capped and sealed with fire-clay, the drum removed from the furnace and set in the cooling stand and rotated while spraying air and water on the drum. In this manner the cooling was accelerated enough to permit two roasts per 8-hour shift.

Pilot Plant Roasting Olympic Ore

The first five roasts on the ore from the Blue Ox and Handy claims of Northern Olympic Peninsula were made using minus 48-mesh ore. It was found necessary to use Pres-To-Log pellets rather than sawdust in the roaster, as sawdust was too bulky and would have cut down the capacity of roaster. These pellets are of pure sawdust pressed to cylinders 1-1/8 inch in diameter and about 1 inch long. It was believed that bulk sawdust could be used conveniently in a multiple hearth roaster of sufficient capacity.

TABLE NO. II

ANALYSIS OF OLYMPIC ORE FROM BLUE OX AND HANDY CLAIMS

Fe	5.05%
Total Mn	33.50%
Acid Sol. Mn	10.40%
SiO_2	27.60%
CaO	7.35%
MgO	1.38%
Ign. loss	6.67%

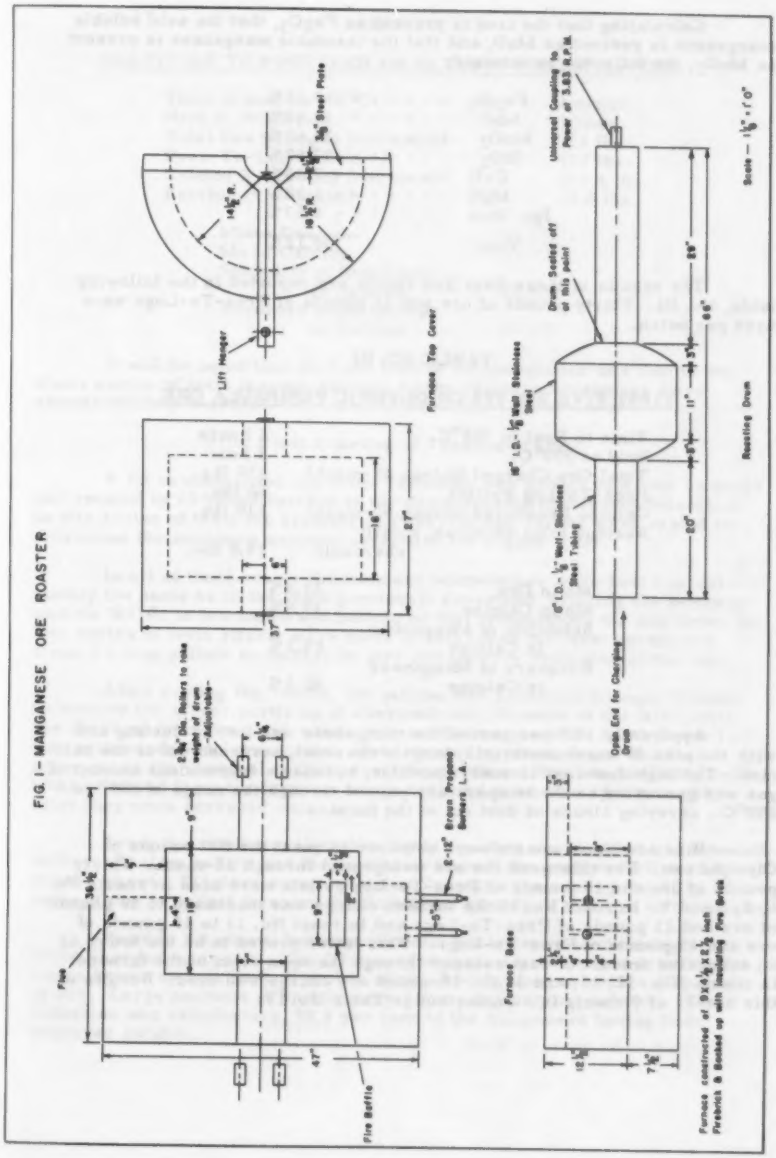

FIG. 1—MANGANESE ORE ROASTER

Calculating that the iron is present as Fe_2O_3, that the acid soluble manganese is present as MnO, and that the insoluble manganese is present as MnO_2, the following is obtained:

Fe_2O_3	7.22%
MnO	13.40%
MnO_2	36.60%
SiO_2	27.60%
CaO	7.35%
MgO	1.38%
Ign. loss	6.67%
Total	100.22%

The results of these first five roasts are reported in the following table, No. III. Thirty pounds of ore and 12 pounds of Pres-To-Logs were used per batch.

TABLE NO. III

FIRST FIVE ROASTS ON OLYMPIC PENINSULA ORE

Time to Heat to 700°C.	2 hours
Held at 700°C.	1 hour
Total Ore Charged (minus 48-mesh)	150 lbs.
Pres-To-Log Pellets	60 lbs.
Calcine Recovered (minus 50-mesh)	110 lbs.
Residue (plus 50-mesh, mostly charcoal)	19.8 lbs.

Mn in Ore	33.8%
Mn in Calcine	37.9%
Solubility of Manganese in Calcine	89.2%
Recovery of Manganese in Calcine	82.5%

Apparently 17.5 per cent of the manganese was lost as dusting and with the plus 50-mesh materials, largely charcoal, screened out of the calcine. The high dust loss is understandable, because a tremendous amount of gas was generated as the temperature passed through the range of 200° to 250°C., carrying clouds of dust out of the furnace.

Nine additional roasts were required to roast the 500 pounds of Olympic ore. For this work the ore was ground through 65-mesh. Thirty pounds of ore and 10 pounds of Pres-To-Log pellets were used in roasts No. 6, 7, 8 and 9. In roast No. 10 the furnace charge was increased to 40 pounds of ore and 13 pounds of Pres-To-Logs and in roast No. 11 to 45 pounds of ore and 15 pounds of Pres-To-Logs. This latter proved to be too heavy as an excessive amount of dust escaped through the open stem of the furnace. In roasts Nos. 12, 13, and 14 the 40-pound ore charge was used. Results of this series of 9 roasts is summarized in Table No. IV.

TABLE IV

ROASTS SIX TO FOURTEEN ON OLYMPIC PENINSULA ORE

Time to heat to 700°C.	2 hours
Held at 700°C.	1 hour
Total Ore Charged (-65 mesh)	325 lbs.
Pres-To-Log Pellets	107 lbs.
Calcine Recovered (-20 mesh)	253.4 lbs.
Residue (+ 20 mesh)	19.8 lbs.

Mn in Ore	33.8%
Mn in Calcine	37.7%
Solubility of Manganese in Calcine	95.0%
Recovery of Manganese in Calcine	87.1%

It will be noted that 12.9 per cent of the manganese was lost in the above series of tests through dusting, as the 20-mesh screenings were almost entirely charcoal.

Pilot Plant Roasting of Tasmanian Ore

A lot of manganese ore from Tasmania was ground to minus 35-mesh and roasted in 40-pound batches in the drum roaster previously described. In this series of tests the amounts of Pres-To-Log pellets were varied to determine the minimum quantity necessary for a good roast.

In all of these roasts the time and temperature were held approximately the same as in the tests previously described, bringing the temperature to 700°C. in two hours and holding at that temperature for one hour. In this series of tests efforts were made to determine the least quantity of Pres-To-Log pellets necessary to give satisfactory reduction of the ore.

After cooling the roasts, the calcine was screened through 20-mesh to remove the larger particles of charcoal; and, in some of the later tests, the charcoal from previous roasts was used to augment the fresh Pres-To-Log pellets added to new roasts. One interesting phenomenon was that in many cases the charcoal pellets, even though the calcine was perfectly cold when removed from the furnace, would heat and catch fire spontaneously after they were screened out.

From the results recorded in Table No. V it was decided that 6 pounds of Pres-To-Log pellets was the minimum amount for good reduction of 40 pounds of ore. Thirteen more roasts on Tasmanian ore using the 40 to 6 ratio of ore to pellets were made. In all, 840 pounds of this ore were roasted.

Besides the above, two experimental roasts were made using other kinds of reducing agents. The first used a product precipitated from sulfite liquor known as Indulin A, 6 pounds of which were used to reduce 40 pounds of ore. Large amounts of vapors were given off, carrying out dust. The reduction was satisfactory, 98.8 per cent of the manganese having been rendered soluble.

TABLE V

RESULTS OF EIGHT ROASTS MADE ON TASMANIAN MANGANESE ORE

Roast No.	Pounds Ore (48.2% Mn)	Pounds Pres-to-Logs	Calcine: Pounds Calcine	Calcine: Per cent Mn	Calcine: Per cent of Mn Acid Sol.	Pounds Mn in Ore	Pounds Mn in Calcine	Recovery of Mn in Calcine
1	40	15	22.5	60.1	98.6	19.28	13.5	70.0
2	40	10	26.0	60.9	98.5	19.28	15.9	82.4
3	40	10	23.0	--	--	19.28	--	--
4	40	8	24.0	61.3	98.9	19.28	14.7	76.2
5	40	6	22.0	60.6	99.1	19.28	13.3	69.0
6	40	10	22.8	58.7	99.4	19.28	13.4	69.5
7	40	8	23.2	--	--	19.28	--	--
8	40	4	27.0	58.1	97.0	19.28	15.7	81.4
ave.	40	8.9	23.8	59.8	98.9	19.28	14.4	74.8

NOTE: (The low recovery, 74.8 per cent is due almost entirely to dust blown out of the furnace by the vigorous evolution of gases from the wood reducing agent.)

Another 40-pound batch of ore was roasted with 1.5 pounds of No. 5 fuel oil as a reducing agent. Poor reduction resulted because the oil was mixed with the ore before introduction into the furnace. During the heating period the oil evidently volatilized and escaped before the temperature rose sufficiently to effect reduction. It is evident that when oil is used as a reducing agent it must be dripped into the hot calcine in order to be effective.

Briquetting With Reducing Agent

The proposition that the manganese ore might be satisfactorily reduced if briquetted with the reducing agent was examined. The briquettes were prepared by mixing the ore with the requisite amount of wood shavings moistening, with sulfite liquor, and briquetting. The briquettes were enclosed between two scorifying dishes and heated in an electric muffle furnace for 1½ hours at 730°C., and on removal from the furnace they were quenched directly in the acid leaching solution containing about 40 grams sulfuric acid per liter. The results of these tests are shown in Table VI.

TABLE NO. VI

BRIQUETTING TESTS ON OLYMPIC PENINSULA ORE

No.	Gms Ore	Gms Wood	Gms 70% Sulfite Liquor	Time of Pressing Min	Pressure psi	Roast Hours Time	Roast Temp. °C.	Solubility of Mn %
1	140	30	60	momentary	500	1.5	750	87.7
2	140	30	60	"	500	1.5	750	93.1
3	140	40	40	5	12,000	1.5	750	97.3
4	140	40	40	1	10,000	1.5	750	79.8
5	140	40	40	momentary	2,000	1.5	750	89.1

It will be noted that reasonably good solubility of manganese was obtained in No. 2 and 3. The filtration was excellent as the charcoal apparently acted as a filter aid. This work was not pursued further because a large scale briquetting apparatus and special shaft roaster would have had to have been set up to test the process on a larger scale.

To speculate on the advantages of briquetting manganese ore with the reducing agent and roasting in a shaft furnace with indirect heating, it may be that the resulting roasted product could be leached by percolation, thus avoiding troublesome washing and filtration problems.

LEACHING AND PURIFICATION

Experience with the extraction of zinc from zinc calcines, as well as manganese leaching processes described in the literature, served as a guide for working out a leaching and purification process for the production of a manganese sulfate solution of sufficient purity to feed to the electrolysing cells. As simple a process as possible was desired so as to combine the leaching and purification into one operation. The Tainton process of leaching a zinc calcine dissolves the zinc and precipitates the iron in one batch operation, carried out as follows:

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A mechanically agitated tank is filled with zinc-spent electrolyte (cell acid) and 90 to 95 per cent of the calcine (impure zinc oxide) necessary to neutralize the acid is added. Agitation is continued until all the zinc possible has been dissolved from the calcine. Incidental with this treatment, a certain amount of iron dissolves as ferric sulfate, but a small amount of ferrous sulfate is inevitably present. This ferrous iron is more difficult to precipitate than ferric iron; so enough manganese dioxide is added to oxidize it to the ferric state. Then the addition of calcine is carefully continued until the acid is neutralized. "Neutral" zinc sulfate has a pH of about 5, whereas ferric hydroxide precipitates at a lower pH of 3 to 4; so the iron can be removed and thrown into the leach residue in one step and thus give a reasonably good extraction of zinc. It was conceived that the same scheme could be used for leaching manganese ore calcine. One difference between a zinc calcine and manganese calcine is that the zinc calcine was roasted under oxidizing conditions and the manganese calcine under reducing conditions; therefore the iron in a zinc calcine is largely ferric and that in a manganese calcine is in the ferrous state. Since ferrous iron is very difficult to precipitate as the hydroxide, it must be oxidized to the ferric state in the manganese leach before the final neutralization and iron precipitation.

Preliminary beaker tests using Olympic Peninsula manganese calcine gave encouraging results. It was found that the ferrous iron went into solution as ferrous sulfate, but that this could be readily oxidized with pyrolusite (MnO_2) and then precipitated by the addition of a slight excess of calcine. The use of pyrolusite as an oxidizing agent has the advantage that no undesired element is introduced into the solution; only the manganese equivalent to the ferrous iron is dissolved.

The precipitation of ferric hydroxide has the property of removing certain impurities from the solution, notably arsenic and antimony, thus a manganese leach conducted as described above serves not only as a means of dissolution of the manganese but also as a means of removal of iron, arsenic, antimony, and, incidentally, aluminum.

PILOT PLANT LEACHES

In the pilot plant leaches attempts were made to use a process known as "reverse leaching" in the hydrometallurgy of zinc. Briefly, it consists of neutralizing the calcine with acid rather than neutralizing acid with calcine. Practically, reverse leaching can be done by pulping all the calcine necessary for a leach, with enough solution so that it can be readily stirred, then gradually adding acid to this pulp. This is in contrast with the usual way of leaching, which consists of starting a leach by filling the agitation tank with the solvent and adding calcine until the acid is neutral. The reverse-leaching method has the advantage that the pH of the solution need never get low enough to dissolve certain acid soluble impurities, notably silica. For example, if the tank is filled with acid solution and the addition of calcine is begun, the first portion of calcine gets a strong acid treatment which immediately removes the soluble manganese; and the residue itself is exposed to strong acid, peptizing silica. As calcine additions are continued, the pH gradually rises to an isoelectric point which causes the peptized silica to precipitate as a gel difficult to filter. Using the reverse system of leaching, it is believed that the pH can always be held at a sufficiently high figure to prevent the initial peptization of silica, thus avoiding the formation of the silica gel.

The pilot-plant leaching equipment consisted of two agitation tanks made from stainless-steel-clad coffee percolators from Navy surplus. These round-bottomed tanks, equipped with a steam jacket for heating, permit the agitation of 200 liters of pulp. It was recognized that the stainless steel cladding is not impervious; so they were kept coated on the inside with Tygon paint. One such tank was equipped with a lightning mixer and served as a leaching tank; another was equipped with a homemade propeller stirrer and served as a purification tank; others were used for neutral solution storage. Acid for leaching was made up in two crocks, one of 50 gallons capacity and the other 100 gallons. A six-frame 1 x 1 foot filter press was used for filtration with the frames covered by pieces of woolen blanket backed up with unglazed Kraft paper. In our first leach a 1 x 1 foot Oliver filter, canvas covered, was tried but it did not prove satisfactory because it gave muddy filtrate and was quickly blinded.

According to available data, all efforts to filter the strong solution from the leach residues from Olympic Peninsula ores were unsuccessful because of gelatinous silica. It has been necessary to resort to countercurrent washing, which may introduce too much wash water.

It was possible to filter the product through a Shriver press though it had a considerably higher solids content than normal. For example, in the first pilot leach run, when a 200 G/L acid solution containing no manganese was used, all the manganese required to build the solution up to the desired level had to come from the ore. This resulted in a pulp containing about twice the amount of solids which would result from the use of a spent electrolyte containing 100 G/L acid and 50-60 G/L manganese. The small Shriver press could handle this pulp fairly easily, although the large amount of solids made it necessary to clean the press at frequent intervals. Table VII gives the results of the pilot plant leaching.

It is postulated that the charcoal from the roast acted as a filter aid and that the reverse leaching aided in preventing the formation of a silica gel. The use of MnO_2 or raw ore to oxidize the iron and cause it to precipitate, by stopping the leach at a pH of five or better, gave a satisfactory purification for iron, arsenic, and antimony. In the case of the Olympic ore, no sulfide purification was found to be necessary, as spectrographic examination showed that the solution contained mere traces of Ni, Co, Cu and Mo. Also manganese dioxide produced from these solutions met Signal Corps purity specifications.

TABLE NO. VII

PILOT LEACHES ON OLYMPIC PENINSULA ORE

Leaching	No. 1	No. 2	No. 3
Charge-Calcine (37.7 % Mn) Kg	57.7	50.0	50.0
Leach Solution (205 G/L H_2SO_4) - liters	190		
(216 " " , 15.9 G/L Mn) - liters		135	135
Minimum pH during leaching	1.5	2.6	2.9
Purification Agents Com. MnO_2, (58.6 % Mn) Kg	2.72	2.5	2.5
Raw Ore (33.8 % Mn) Kg	1.0		
Leaching Time, Hours	51.0	25.17	24.67
Filtering (Shriver Press)			
Strong Solution before filtering - G/L Mn		141.8	141.6
Strong Solution to Storage - Liters	135	115	140
G/L Mn	79.2	121.0	98.2
Wash Solution, Liters	166	72	120
Wash Solution G/L Mn	26.6	15.0	18.5
Washed Residue, dry weight, kgs.	40.7	39.5	24.0
% Mn	12.6	14.3	13.4
% water sol. Mn	3.24	3.3	3.04
Unwashed Residue, dry weight, kg.*			13.7
% Mn			17.3
% water sol. Mn			8.3
% Recovery (% of Mn in strong sol. and wash)	65.0	66.8	71.2
% Leach recovery (Mn in residue to Mn in solid feed)	78.7	72.2	72.3

* The Shriver press pump plugged up at the end of the charging period and the cake had to be removed without washing.

LEACHING TASMANIAN ORE CALCINE

After the foregoing results on leaching Olympic Peninsula ore were obtained, five leaches were made using calcine from the Tasmanian ore. These leaches were made by the same reverse-leach method as previously described. Ease of filtration varied considerably among the various tests, and it cannot be stated that the optimum conditions have been worked out. It is evident that a thorough study of the factors affecting coagulation and filtration should be undertaken. The fact that ease of filtration varies so greatly from one leach to another indicates that reasonably easy filtration would be attainable if the optimum conditions of leaching were known.

Leach solutions from the Tasmanian ore showed traces of cobalt, nickel, and copper; so a purification using barium sulfide was resorted to. This was carried out by dissolving the barium sulfide, about 1 per cent of the calcine, in water and stirring it into the neutral leach solution. Pink manganous sulfide precipitated immediately but gradually blackened as the other sulfides came down. These purifications were allowed to stand overnight and were then filtered. Filtration through the Shriver filter press was easy and those impurities remaining were scarcely detectable spectrographically.

The extraction results of manganese from two Tasmanian ore leaches are shown in the following tables, Nos. VIII and IX.

TABLE NO. VIII

LEACH NO. 2 MANGANESE EXTRACTION FROM TASMANIAN ORE CALCINE

IN	Kg	Kg Mn
Calcine (55.5 % Mn)	52.0	28.86
MnO_2 (58.6 % Mn)	0.5	.29
		29.15 total in
OUT		
Residue	18.99	2.90
(15.27% Mn)		
(11.90% Ac. Sol. Mn)		
(4.50% H_2O Sol. Mn)		
(14.83% Fe)		
(5.53% Si)		
Purification Residue	1.42	.15
(10.80% Mn)		
(8.15 % H_2O Sol. Mn)		3.05 total out
Leach Extraction		89.6%

TABLE NO. IX

LEACH NO. 3 MANGANESE EXTRACTION FROM TASMANIAN ORE CALCINE

IN	Kg	Kg Mn
Calcine (55.5% Mn)	41.38	22.97
Raw Ore (45.6% Mn)	0.20	.09
		23.06 total in
OUT		
Slime Residue	11.80	1.32
(11.20% Mn)		
(6.94% Ac. Sol. Mn)		
(2.15% H_2O Sol. Mn)		
(14.21% Fe)		
Sand Residue	5.306	1.02
(19.22% Mn)		
(15.49% Ac. Sol. Mn)		
(0.90% H_2O Sol. Mn)		
(19.24% Fe)		
Purification Residue	1.22	.13
(11.05% Mn)		
(7.94% H_2O Sol. Mn)		2.47 total out
Leach Extraction		89.3%

* See next page.

* In this test, the sand which had accumulated in the bottom of the leach tank was filtered and analysed separately. The results indicate that a finer grind than minus 48-mesh would give better extraction.

ELECTROLYSIS

As mentioned in the introduction, the principal object of this research was to determine the proper conditions of electrolysis to produce a battery-active manganese dioxide that would pass certain tentative specifications issued by the U. S. Army Signal Corps as contained in their pamphlet marked SCL - 3117 - D, 18 March, 1952 - Manganese Dioxide, Synthetic.

The more important specifications contained in this publication are:

Chemical Composition

Available oxygen as % MnO_2	85% min.
Total manganese as % Mn	58% "
Adsorbed moisture as % H_2O	3% max.
Iron as % Fe (soluble HCl)	0.3% max.
Silicon as % SiO_2	0.5% "
Total alkali and alkaline earth metals	1.0% "
Total Heavy Metals (other than Fe, Pb)	0.3% "
Lead as % Pb	0.2% "
pH	4.0-8.0

The apparent density shall be between 20 and 30 grams per cubic inch.

Particle Size - The synthetic manganese dioxide shall be of such size that at least 65% of the material shall pass through a U. S. Standard Sieve #200 and at least 90% through a U. S. Standard Sieve #100.

Crystalline Phase - When crystallographic and micro-structural analysis of the synthetic manganese dioxide are made as described . . . . there shall be evidence of a predominance of the imperfectly crystallized phase known as gamma MnO_2.

Particle Morphology - When examined in the micron- and submicron-size range, at direct magnification from 5,000 to 20,000 diameters, the particles shall present irregular shapes with no evidence of cleavage, i.e., with non-rectilinear profiles having powdery or nebulous rather than sharp, well-defined edges.

X-Ray Diffraction Pattern - The X-Ray diffraction pattern shall be characterized by the diffuse-line pattern of gamma MnO_2. For the purpose of this specification, the significant lines (d) of gamma MnO_2 and their respective relative intensities (I) for iron radiation are as follows:

d	I
4.00	5
2.45	7
2.14	7
1.65	10
1.40	5
1.06	3

Cell Construction - The Signal Corps tests were made on standard test cells whose construction is described in the fore-mentioned pamphlet SCL-3117-D.

Capacity Tests - The standard cells are tested for low drain capacity and high drain capacity. The conditions of these tests are the following:

	Low Drain	High Drain
Type of Discharge	continuous	continuous
Discharge Resistance	166 2/3 ohms	16 2/3 ohms
Test End Voltage	1.13 volts	1.0 volt
Discharge Temperature	70°F (50% R.H.)	70°F (50% R.H.)
Minimum Hours Permitted	130	5.5

The tests on electrolysis were carried out on two scales, the smaller tests being in 4-liter beakers. Larger-scale tests were made in a Karbate cell, 36 inches deep and 7 by 14 inches in cross section. Figure 2 shows the electrolysing bench for the small-scale work. The 4-liter beakers were set over small hot plates to furnish the necessary heat. One of the cells was controlled by a thermoregulator and relays which switched all of the hot plates off and on. The temperature of the three cells which were not controlled was adjusted to hold the same as the controlled cell by placing insulating bricks around all four cells and opening gaps in the bricks for adjustment. The cells were all connected in series with an ampere-hour meter. Direct current was furnished by a copper-oxide rectifier. These small cells were not fed continuously as the cell volume was large compared to the rate of manganese-dioxide deposition. This permitted feeding once or twice daily without appreciable fluctuation of the manganese and acid content of the cells. The conditions of the cells were maintained by titrating acid and manganese daily and calculating the amount of electrolyte to remove and replace with neutral manganese-sulfate solution. Since evaporation was rapid because of the high temperature of the electrolyte, distilled water was fed into the cells to hold the electrolyte at a constant level. The cells were covered with micarta boards to impede evaporation and to serve as supports for the electrodes.

SMALL SCALE TESTS - FOUR LITER BEAKERS

Nineteen preliminary tests made in the small cells will not be taken up separately as they were made largely to test out the equipment and make observations concerning the behavior of electrodes. Copper cathodes were tried with both graphite anodes and lead anodes; lead cathodes were similarly tested, and graphite cathodes were also tested. No difference in the anode deposit from the use of the various cathodes could be detected.

Graphite anodes and lead anodes were tried. It was determined, as has been observed by others, that when lead anodes were used the manganese dioxide inevitably contained up to 0.6 per cent lead. Drawing on a fact well known to the electrolytic zinc industry, that cobalt in solution impedes corrosion of lead anodes, the addition of cobalt to the manganese electrolyte was tried, but the effect was not noticeable. Pretreatment of the lead anodes in acidified cobalt solutions was found unsatisfactory so far as lead in the product was concerned.

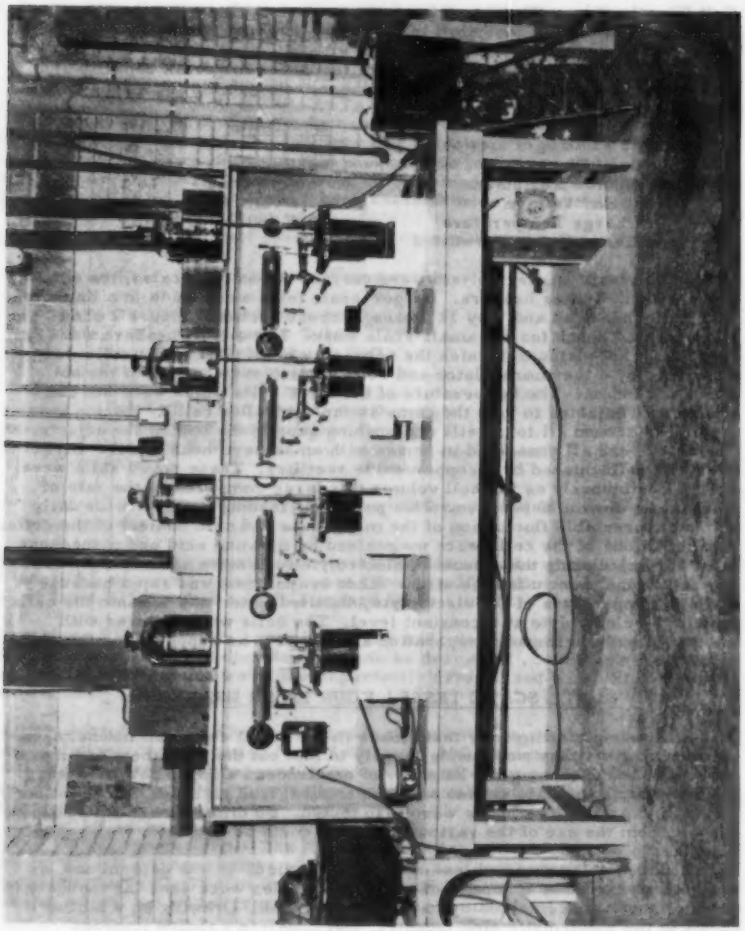

Fig. 2 -- Electrolysing Bench with 4-liter Beaker Cells

One valuable observation on the use of lead anodes was made. It was noticed that that portion of the anode above the solution line became coated with white lead sulfate. Since this could be washed down into the solution by spray and condensate, it was postulated that this corrosion above the solution line might be the source of the lead which was contaminating the manganese dioxide product. In one run using lead anodes, the top half of the deposit was kept separate from the bottom half and the two halves were analysed separately for lead. The top portion contained 0.52 per cent lead and the bottom half only 0.15 per cent. This observation led to the development of the sleeved anode stem to be described later.

Lead Alloy Anodes

Universal practice in the electrolytic zinc industry is to use lead anodes containing 0.5 to 2 per cent silver. This silver has the property of inhibiting anode corrosion and contamination of the electrodeposited zinc. Where insoluble anodes are used in the electrowinning of copper, antimonial lead is most frequently used. A special alloy for anodes for manganese metal electrowinning has been patented by Fink and Kolodney.[22] These are lead base alloys containing cobalt and tin. The inventors claim that the use of these alloys impedes the precipitation of manganese dioxide, undesirable in the electrolytic manganese metal process.

Four-beaker cells were set up to test the three alloys mentioned above, as well as pure lead. As previously mentioned, it was indicated by experiments that the principal source of lead in the manganese dioxide might be from corrosion of the lead anodes above the solution line. Since plastic or synthetic paint on and above the solution line failed to stand up under the high temperature required (95°C.), the anodes were cast in rods 1" in diameter with a Vicor glass sleeve covering that portion above the solution line and extending about an inch below the solution. Only the contact above the cell cover was exposed. The following alloys were used.

Test No.	Anode
S-1	Pure lead
S-2	Lead with 0.5% Co , 3% Sn
S-3	7% antimonial lead
S-4	1% silver lead

The pure lead cathodes, two for each cell, were of identical size and shape with the anodes and sleeved with Vicor glass.

22/ Fink, C. G. and Kolodney, M., "Anodes for the Electrowinning of Manganese; Alloy Anode of Lead, Tin and Cobalt," Trans. Electrochem Soc. 76, 401-25 (1939).

Other conditions were:

Electrolyte	- 90 G/L H_2SO_4 50 G/L manganese
Temperature	- 94° - 95° C.
Current density	- 5 amps. per square foot
Average voltage	- 2.3 for all cells
Length of run	- 28 days
Current efficiencies	- all about 103%

These four cells behaved very much the same. The manganese dioxide deposits from all four of them were very hard and dense, no scaling whatsoever being observed. Cell No. S-3 was discontinued after 14 days because of trouble with the heater.

The anode products were stripped, rinsed with water, crushed, and ground through 325-mesh in a porcelain jar mill using alumina balls. It was washed repeatedly by shaking with water, settling, and decantation. One wash with dilute ammonium hydroxide was used to completely neutralize the acid. The products were tested for bulk density, pH, and lead content.

The lead was determined by the dichromate method and the pH as directed by the Signal Corps.[23] The bulk density was taken with a Scott Volumeter.

Test No.	pH	Bulk Density G/cu in	% Lead
S-1	7.0	29.3	.084
S-2	7.2	29.7	.052
S-3*	3.0	21.5	.055
S-4	7.25	29.3	.032

Signal Corps specifications are that the pH must be 4 to 8, the bulk density must exceed 20 and lead must be under 0.2 per cent. S-1, S-2 and S-4 all exceeded these specifications. Since S-4 contained the least amount of lead, this sample was sent to the Signal Corps laboratory at Fort Monmouth, N. J., for battery activity testing. The results were as follows.

Analysis of S-4 (Signal Corps)

Available oxygen as MnO_2	88%
Total manganese	57.6%
Moisture	1.90%
Iron	0.02%
pH	4.2
Apparent density, grams per cubic inch	27.7
Lead	0.04%

[23] One gram was mixed with 100 ml of water and held at near boiling for 1 hour, keeping the volume at 100 ml by additions of water. The sample was filtered and the pH of the filtrate was taken.

* This sample was a short run and was washed and prepared separately.

Screen Analysis of S-4 (Signal Corps)

On 80-mesh	0%
On 100-mesh	0%
On 150-mesh	0%
On 200-mesh	0%
On 250-mesh	0.2%
On 325-mesh	14.0%
Through 325-mesh	85.8%

Capacity Test Data (Signal Corps)
(Test on cells prepared from S-4)

	High Drain Test	Low Drain Test
Average initial service	6.8 hours	132.7 hours
Minimum initial service (Signal Corps Specification)	5.5 hours	130.0 hours

It will be noted that this sample passed both the high and low drain battery tests. However, the following is quoted from the Signal Corps report on this material.

"As will be noted, the material is a polyphase mixture of alpha and rho. A review of all these tests indicate that although the material does not exhibit the desired "gamma" phase structure, cells made with it did pass the capacity requirements of Specification SCL - 3117A."

"However, spectrographic analysis for the sample showed a potassium content of 2 per cent. Our experience has been that synthetic manganese dioxide containing any alkali or alkaline earth element in excess of approximately 0.5 per cent will have poor shelf life....."

The contamination of the product with potassium is difficult to understand as the writer is not familiar with any chemical or electrochemical reaction which would cause any of the alkali or alkaline earth elements to precipitate on the anode of an electrolytic cell from a highly acid electrolyte. Since the manganous sulfate solution used was leached from calcine reduced from wood, it is believed that some of the potassium came from this source. It would be difficult, however, to avoid the accumulation of alkalis and alkaline earths in solutions produced from natural ores, especially where the process is cyclic as would be the case in a process of producing electrolytic manganese dioxide from reduced manganese ore. The spent electrolyte returned to the leach would inevitably pick up sodium, potassium, and mangnesium which would accumulate in the solution. The only way to control such a build-up is to bleed off solution. This brings up the problem as to what can be done with the bleed-off solution. The best way would be to evaporate it to dryness and market the manganous sulfate, provided that a market were available. Another possibility is to precipitate the manganese with ammonium hydroxide and recover manganese hydroxide for returning to the leach. The filtrate could be evaporated and dry ammonium sulfate marketed.

Since the maintenance of the high temperature of the electrolyte will contribute heavily to the cost of the process and also brings up serious pro-

blems of materials of construction of the cells and solution piping, two small cell runs, S-5 and S-6, were run at 65°C. with a high acid electrolyte to see if a coherent deposit of manganese dioxide would result. The results were as follows:

Test S-5

Anode	- 1% silver lead, 1" rod, sleeved with Vicor glass
Cathodes	- Copper
Electrolyte	
Acid	- 283 G/L
Manganese	- 50 G/L
Current density	- 45 amps/sq ft , later 22.5
Temperature	- 65°C.
Volts	- 2.5

The manganese dioxide produced permeated the whole solution, very little sticking to the anode. The test was discontinued after 24 hours, and the product filtered out, washed, dried, and pulverized. The material was dark brown instead of the usual black and had a bulk density of only 10 grams per cubic inch (Scott Volumeter). It was not tested further.

Test S-6

Anode	- 1% silver lead, 1" rod, sleeved with Vicor glass
Cathodes	- Graphite
Electrolyte Acid	- 335 G/L
Manganese	- 25 G/L
Current Density	- 15 amps/sq ft
Temperature	- 65°C.
Voltage	- 2.7

Results: This test was run for 10 days, but was discontinued due to the fact that the cell filled with sludge, very little of the deposit sticking to the anode. Since the deposit was light brown and of very low bulk density it did not seem worth-while to have it tested for battery activity.

Tests S-7, S-8, S-9, S-10

These cells were run to investigate the behavior of flat lead anodes instead of cylindrical used in the previously mentioned small-scale tests. Also different methods of protecting the anode stems were tried.

Test S-7, 8, 9, 10

Anodes - 1% silver lead, exposed portion 2" wide, 7" long, 1/4" thick.
S-7 - Anode stem protected by a Pyrex glass tube slipped on and cemented with rubber.
S-8 - Anode stem protected by a Karbate sleeve, not cemented.

S-9 - Anode stem protected by a Karbate sleeve, cemented with rubber.
S-10 - Same as S-9.
Cathodes - Graphite for all four.
Electrolyte
Acid - 90 G/L
Manganese - 50 G/L
Current density - 5 amps/sq ft
Temperature - 95°C.
Voltage - 2.3 ave.
Duration - 23 days
Current Efficiency - Average 102%.

Lead content of products:
S-7 - 0.063%
S-8 - 0.073%
S-9 - 0.073%
S-10 - 0.041%

No striking difference in the lead contents of the cathodes was noticeable. The Karbate anode sleeves in tests Nos. S-8, S-9, and S-10 were not satisfactory, as every bit of that portion of the sleeve that extended below the acid in the cell was completely destroyed by the electrolytic action.

The somewhat higher average lead content of the manganese dioxide product from this series over run S-4 is probably due to two influences. First, the stems of the anodes were not as thoroughly covered as was provided by the Vicor sleeve of S-4; and second, the flat anodes do not hold the deposit of manganese dioxide as tightly against the surface, thus there is more electro-chemical action behind the deposit.

Pilot Scale Electrolytic Tests

Large-scale tests were conducted to study the electrolytic phenomena at a scale nearer commercial so as to better anticipate troubles which might arise in a commercial installation, and also to produce sufficiently large quantities of the manganese dioxide for thorough testing.

Test P-1

Solution	- Leached from Olympic Peninsula Ore.
Container	- A 40 gallon crock, covered with micarta board 5/8" thick.
Anode	- 2 6-1/4" x 1-1/2" graphite slabs, 22-3/4" submerged.
Cathodes	- Same as anode, 2 in number, spaced 2" from anode, center to center.
Electrolyte	
Acid Average	- 40.6 G/L
Manganese average	- 75.0 G/L
Temperature	- 94° - 95°C.
Average cell voltage	- 2.6
Current Density	- 10.55 amps/sq. ft.
Duration of Run	- 5 days
Current Efficiency	- 93 %

This run was made to be as nearly self-controlled as was considered feasible at that time. The cell was maintained at the proper temperature by quartz-covered immersion heaters controlled by a mercury thermoswitch which activated a relay to throw the heating elements on and off. The cell was equipped with a solution-level indicator consisting of two platinum prongs which would make contact with the solution surface to complete a 110-volt circuit and light a 5-watt light. When the surface of the solution got too low from evaporation, the light would go out, indicating the necessity of adding distilled water.

The acidity of the cell was controlled by titration with standard sodium carbonate solution, using methyl orange as an indicator. Titration was carried out every two hours, day and night. After every titration, cell acid was removed as indicated and replaced with hot, neutral manganese sulfate solution, 98 G/L manganese.

The cell was stripped after a 5-day run, 24 pounds of manganese dioxide being obtained. The deposit was not smooth as it had cracked and curled, giving it the appearance of the bark of an old elm tree. The material was rinsed, dried, ground in Abbé pebble mills, screened through 325-mesh and thoroughly washed by repeatedly stirring up with water, allowing to settle, and decanting. This had to be repeated twelve to fifteen times to get the pH up to 4.0, Signal Corps Specifications. Fifteen pounds were sent to the Signal Corps laboratory at Fort Monmouth, N. J. They reported as follows.

Analysis of P-1 (Signal Corps)

Available oxygen as MnO_2	89.9%
Total manganese	61.3%
Moisture	2.0%
Iron	0.03%
Silica	0.02%
pH	4.3
Apparent density, grams per cubic inch	17.4
Lead, less than	0.02%

Screen Analysis of P-1 (Signal Corps)

On 80 mesh	0.0%
On 100 "	0.3%
On 150 "	1.2%
On 200 "	3.0%
On 250 "	1.2%
On 325 "	42.1%
Through 325 mesh	52.2%

Capacity Test Data (Signal Corps)
(Test on cells prepared from P-1)

	High Drain Test	Low Drain Test
Average initial service		
(tested day after manufacture)	6.4 hours	124.1 hours
(tested after 10 day storage)	6.3 hours	100.4 hours
Minimum initial service (Signal Corps Specification)	5.5 hours	130 hours

Micro-optical investigation revealed the material to be a polyphase mixture of alpha, beta and gamma MnO_2, in which the Gamma was predominant.

The following is quoted from the Signal Corps report on sample P-1.

"A review of all these test data shows that the material did not meet the requirements of synthetic manganese dioxide specification No. SCL-3117A. It is believed that this is so because of the polyphase characteristics of the materials and also the distribution of particle size of the material. The sample has been ground too fine, which probably accounts for its low apparent density."

Test P-2

Solution	- Leached from Olympic Peninsula Ore.
Container	- Karbate Cell, 7" x 14" cross-sectional area, 36" deep, covered with 5/8" micarta board.
Anode	- Graphite slab, 6 1/4 x 1 1/2 x 31" immersed length.
Cathodes	- Walls of Karbate cell.
Electrolyte	
Acid Average	- 80 G/L
Manganese Average	- 52 G/L
Temperature	- 94° - 95°C.
Average cell voltage	- 2.9
Current Density	- 10.5 amps/sq ft
Duration of run	- 12 days
Current efficiency	- 74%

This run duplicated the conditions of P-1 except that the Karbate cell was used instead of the crock, Karbate cell walls were used instead of graphite, and that the average acidity was held at about twice the figure as P-1, namely, at 80 G/L rather than 40.6 G/L. The feed used in run P-2 was the spent electrolyte from P-1, bringing the acid up from 40 G/L to 80 G/L and reducing the manganese accordingly.

One auxiliary test was made to determine the amount of heat necessary to maintain the cell temperature at 95°C. This was done by timing the heaters. It was found that they were on 17.7 per cent of the time providing 1250 watts steady heat. Since one should be able to produce 0.2 pounds of manganese dioxide per hour under these conditions, it is indicated that if the solutions were heated and maintained at 95°C. by electrical heating, 6250 watt hours per pound of manganese dioxide would be required.

The manganese dioxide deposit from P-2 had the same cracked and scaly appearance as P-1. Apparently the deposit started out as a coherent envelope surrounding the graphite anode, but later on this must have split up, thus allowing electrolytic action to take place in the cracks. This caused the hard initial deposit to be forced up and away from the graphite, and a softer material deposited under the original hard coating.

When the deposit was stripped, some of the originally deposited hard scale was separated from the softer material filling the cracks beneath and

between the hard scales. These two samples were washed and ground and sent to the Signal Corps for morphology examination, along with the bulk sample which was a composite of the scale and soft material. Only the composite sample was examined for battery activity after screening through 325-mesh and washing as done on sample P-1.

Analysis of P-2 (Signal Corps)

Available oxygen as $Mn O_2$	90.2%
Total manganese	60.5%
Moisture	1.3%
Iron	0.03%
Silica	0.06%
pH	4.0
Apparent density, grams per cubic inch	18.3
Lead	0.02%

Screen Analysis of P-2 (Signal Corps)

On 80-mesh	0%
On 100-mesh	1.2%
On 150-mesh	1.1%
On 200-mesh	4.2%
On 250-mesh	1.4%
On 325-mesh	51.0%
Through 325-mesh	41.1%

Capacity Test Data (Signal Corps)
(Test on cells prepared from P-2)

	High Drain Test	Low Drain Test
Average initial service	6.4 hours	100.2 hours
Minimum initial service (Signal Corps Specification)	5.5 hours	130.0 hours

Micro-optical investigations revealed the following:

"Results of electron microscopy and electron diffraction reveal that all samples are polyphase mixtures of manganese dioxide phase types; gamma MnO_2 is the dominant phase with varying proportions of the other phses."

"Results of compositional study by emission spectroscopy reveal no significant differences in composition in the three samples."

"Sample A, the composite sample, is characterized as predominantly gamma MnO_2 with minor beta MnO_2 (pyrolusite). The electron microscope reveals many well crystallized bladed particles."

"Sample B, the hard crust material, is characterized as predominantly gamma MnO_2 with a trace of beta MnO_2. The electron microscope reveals typical gamma MnO_2 morphology."

"Sample C, the soft friable material, is characterized as predominantly gamma MnO_2 with minor phases of both beta MnO_2 and alpha MnO_2 (crypto-

melane type). The electron microscope reveals several morphologies including anhedral, bladed and acicular."

"The presence of alpha phase in sample C and not in the composite is not readily understood."

Remarks by writer: It will be noted that the hard crust material gave the best morphology, being the purest gamma of the three samples of P-2 material. Later work indicates clearly that the best material is that which deposits smoothly on the anode, and which shows a glassy conchoidal fracture, and that, whenever a scaly deposit containing soft material is obtained, it does not fulfill the requirements for gamma morphology or battery activity.

Test P-3

Solution	- Made by dissolving commercial fertilizer grade manganese sulfate and purifying the same by: (a) Adding 1 G/L iron as ferric sulfate and precipitating the iron as ferric hydroxide by the addition of calcium carbonate. (b) The filtrate from (a) was given an additional purification by agitating with 1 G/L barium sulfide followed by filtration.
Container	- The Karbate cell as described under Test P-2.
Anode	- Graphite slab as in Test P-2.
Cathodes	- Walls of Karbate cell
Electrolyte	
Acid average	- 40 G/L
Manganese average	- 78 G/L
Temperature	- 95°C.
Average voltage	- 2.93
Current density	- 15 amps. per sq. ft.
Duration of Run	- 77 hours
Current efficiency	- 83.08%

NOTE: The commercial manganese sulfate used for making the solution to run P-3 was evidently prepared from the ore by leaching with sulfur dioxide, as a strong odor of hydrogen sulfide was given off from the first and the cell electrolyte always contained suspended sulfur. Sulfur sublimed out of the electrolyte and accumulated on the cell cover to a thickness of 1/2 inch. All of these phenomena are attributed to the presence of thionates and other sulfur complexes formed when manganese dioxide is reduced with sulfurous acid.

This run and all subsequent pilot runs were equipped with an electrolytic solution feeder as described by Ashman.* This consisted of an oxy-hydrogen generation flask with two platinum electrodes in 10 per cent sulfuric acid. The rate of evolution of the oxy-hydrogen mixture was adjustable by a variable resistance in a direct current circuit to the platinum electrodes.

* "An Accurate Reagent Feeder for Small Quantities," Ashman, A. O., Eng. and Min. Jour., pp. 98-100, Vol. 151, No. 4, Apr., 1950.

This gas generator was connected to the 20-liter manganese solution storage carboy which fed the manganese dioxide electrolytic cell. Thus the gas from the gas generator displaced the solution in the manganese feed carboy; and, since the rate of generation of the oxy-hydrogen was adjustable, the neutral manganese sulfate solution could be fed at the rate necessary to hold any desired acidity in the manganese dioxide electrolytic cell. By the use of such a feeder the shift work was discontinued. When using such a feeder, care must be taken to keep fire away from the explosive oxy-hydrogen mixture.

The deposit obtained in run P-3 looked about the same as that obtained in previous runs. It was noticed while stripping that about half of the anode surface was covered with a layer of the dioxide about 1/8" thick that stuck so tightly that it was necessary to tear away the graphite to get it loose.

The sample was ground through 200-mesh instead of through 325 as was done in the previous two pilot runs, washed as was previously done to get the pH up above 4 and sent to the Signal Corps for testing.

Analysis of P-3 (Signal Corps)

Available oxygen as MnO_2	88.2%
Total manganese	58.8%
Moisture	3.3%
Iron	0.05%
Silica	0.04%
pH	4.2
Apparent density, grams per cubic inch	17.4
Lead	less than 0.02%

Screen Analysis of P-3 (Signal Corps)

On 80-mesh	1.0%
On 100-mesh	4.2%
On 150-mesh	1.6%
On 200-mesh	9.0%
On 250-mesh	15.6%
On 325-mesh	42.2%
Through 325-mesh	26.4%

Capacity Test Data (Signal Corps)
(Test on cells prepared from P-3)

	High Drain Test	Low Drain Test
Average initial service	6.0 hours	107.2 hours
Minimum initial service (Signal Corps Specification)	5.0 hours	130 hours

Micro-optical investigations revealed that this deposit was single phase gamma manganese dioxide.

Quote: "A review of all these test data indicates that this sample is essentially single phase gamma manganese dioxide of high chemical purity.

It is believed that dry cells made with this sample failed to meet the low drain test specification requirements because of the relatively low apparent density of the sample (i.e., 17.4 gms/in^3). It is believed that the material would have met the specification requirement if it had an apparent density in the 20-30 grams per cubic inch range."

Note by the writer: This sample contained some graphite detached from the anode during stripping which may have accounted for the low bulk density, in part, at least. However, no sample of satisfactory bulk density was prepared from any deposit containing any appreciable amount of soft material, as has been the case in P-1, P-2 and P-3 reported so far.

Another interesting observation about sample P-3 is that its morphology was given as single-phase gamma, even though the current density was 15 amps per square foot. This is the only case where gamma was made at such a high current density. This cell, as previously mentioned, gave off a distinct odor of hydrogen sulfide and sulfur precipitated during electrolysis. The single phase gamma may have some connection with the reducing agents, such as dithionate, present in the feed.

Test P-4

Solution	- From Tasmanian Ore Leach No. 1 and 2
Container	- Karbate cell previously described.
Cathodes	- Walls of Karbate cell
Anode	- As in P-2
Electrolyte	
Acid average	- 90 G/L
Manganese average	- 60 G/L
Temperature	- 94° - 95° C.
Voltage	- Varied 3.1 down to 2.3 then up to 3.3 (perhaps because poor contacts)
Current density	- 15 amps/sq ft
Duration of run	- 14 days
Current Efficiency	- 70%

The product from this run was cracked and scaly as in the previous pilot runs. It was ground through 200-mesh and washed to a pH of 4 +. Half of the sample was examined at the laboratories of the National Carbon Company in Cleveland, Ohio, where it was pronounced satisfactory. The other half was examined at the Signal Corps laboratories at Fort Monmouth. Their reports follow.

Analysis of P-4 (Signal Corps)

Available oxygen as MnO_2	88.9%
Total manganese	59.0%
Moisture	1.62%
Iron	0.09%
Silica	0.26%
pH	3.9
Apparent Density, grams per cubic inch	14.3
Lead ..... less than	0.02%

Screen Analysis of P-4 (Signal Corps)

On 80-mesh	0.0%
On 100-mesh	0.2%
On 150-mesh	0.2%
On 200-mesh	0.2%
On 250-mesh	1.8%
On 325-mesh	41.2%
Through 325-mesh	56.4%

Capacity Test Data (Signal Corps)
(Test on cells prepared from P-4)

	High Drain Test	Low Drain Test
Average initial service	6.3 hours	107.0 hours
Minimum initial service (Signal Corps Specification)	5.5 hours	130.0 hours

The following is quoted from the Signal Corps report.

"It will be noted.....the material is a polyphase mixture of alpha, beta and gamma phase MnO_2 in which the alpha phase is dominant."

Writer's comment: So far as morphology is concerned, this was the worst product produced to date. Also, it was the first sample prepared at a high current density (15 amps/sq ft) and high scid in the electrolyte (90 G/L). This indicated that if acidity were to be maintained at a figure sufficiently high to take half of the manganese out of the solution as it passed through the cell, (90 G/L sulfuric acid is equivalent to 51 G/L manganese deposited as manganese dioxide) then 15 amperes per sq. ft. current density is too high. In test P-2 where the current density was 10.5 amps. per sq. ft. and the average acidity was 80 G/L, a polyphase mixture was also obtained, although the gamma phase predominated in P-2. This indicates that a current density of 10.5 amps per sq. ft. is too high.

Test P-5

This test was designed to duplicate on a large scale the conditions of test S-4, previously described. However, due to a mistaken calculation, S-4 was run at 5 amps per sq. ft. current density while P-5 was run at 15 amps per sq. ft.

Solution	- Leached from Tasmanian Ore
Container	- Karbate cell as previously described
Anode	- 1" silver lead rod, 28" long, sleeve at solution line with Vicor glass
Cathodes	- Walls of Karbate cell
Electrolyte	
Acid average	- 97 G/L
Manganese average	- 55 G/L
Temperature	- 95°C.
Average Voltage	- 3.5
Current Density	- 15 amps. per sq. ft.
Duration of Run	- 21 days
Current Efficiency	- 41%

Note: In this test, it was attempted to increase the current daily to compensate for the constant increase in area of the anode due to the deposition of the manganese dioxide, always trying to hold the current density at 15 amperes per square foot. Thus the first day of the run, 9.3 amperes were used, while on the 21st day 30.5 amperes were used. The amperages required were calculated on the basis that current efficiency was 75 per cent. Actually, it was 41 per cent, thus the increments in current were much too great.

The deposit was broken, scaly and a great amount of electrochemical action, evidenced by white lead sulfate and pitting of the lead, had taken place at the surface of the anode.

The deposit was dried and ground and analysed for lead, of which it was found to contain over 1 per cent. It was not examined further (See Fig. 3).

Test P-6

Solution	- Leached from Tasmanian Ore
Container	- Karbate cell, as described
Anode	- Graphite slab
Cathodes	- Walls of Karbate cell
Electrolyte	
Acid average	- 87.5 G/L
Manganese average	- 50 G/L
Temperature	- 95°C.
Average cell Voltage	- 3.0
Current Density	- 7.5 amps /sq ft
Duration of Run	- 15 days
Current Efficiency	- 91%

This was by far the smoothest and most coherent deposit yet obtained. It was about 3/8-inch thick completely and evenly covering the anode. On removal of the anode from the hot electrolyte the deposit checked due to thermal shock, making the deposit easy to strip. (See Fig. 4) After stripping, it was washed for 12 hours with running water, dried at 98°C. for 24 hours, then ground through 200-mesh and washed and dried as previously described. The Signal Corps reports were as follows.

Analysis of P-6 (Signal Corps)

Available oxygen as MnO_2	90.8%
Total manganese	55.4%
Moisture	1.5%
Iron	0.02%
Silica	-
pH	4.1
Apparent density, grams per cubic inch	24.8
Lead	0.08%

Fig. 3 -- P-5 Anode before stripping. Size of bare Anode shown by rod hanging at upper left.

Fig. 4 -- P-6 Anode before stripping.

Screen Analysis of P-6 (Signal Corps)

On 80-mesh	0
On 100-mesh	0.2%
On 150-mesh	0.2%
On 200-mesh	1.2%
On 250-mesh	5.8%
On 325-mesh	62.0%
Through 325-mesh	30.6%

Capacity Test Data (Signal Corps)
(Test on cells prepared from P-6)

	High Drain Test	Low Drain Test
Average initial service	7.3 hours	143.8 hours
Minimum initial service (Signal Corps Specification)	5.5 hours	130.0 hours

Note: It will be observed that this sample greatly exceeds the specifications for both high drain and low drain tests. Apparently, low current density, 7.5 amps per sq. ft., is the favorable condition for the deposition of gamma manganese dioxide as well as for developing material of high bulk density.

Test P-7

This test was made to try out a silver lead alloy anode under conditions of electrolysis similar to those of the highly successful Run P-6.

Solution	- Leached from Tasmanian Ore
Container	- Karbate cell as described
Anode	- 1% silver lead, flat oval, 4" wide, 1/2" thick at center, 28" submerged length. The stem was protected by a Karbate tube cemented on, this extending from the electrical contact at the top of the stem down an inch below the solution line.
Cathodes	- Walls of Karbate cell.
Electrolyte	
Acid average	- 89 G/L
Manganese average	- 48 G/L
Temperature	- 95.5°C.
Average cell Voltage	- 2.5
Current Density	- 7.5 amps/sq ft
Duration of Run	- 28 days
Current Efficiency	- 89%

The deposit was a smooth unbroken envelope surrounding the anode. It was hard and brittle, but stripped easily.

It has been surmised that when lead anodes were used that the lead contamination would probably be at the interface of lead and manganese dioxide. If this were the case, then abrading the deposit as stripped should wear the inner surfaces of the fractured pieces, throwing the lead into the

fine slimes. This was tried on P-7. The stripped deposit, 11,414 kilograms, was placed in a large Abbe jar mill with about 20 liters of water. The mill was turned for about one hour, no pebbles being used. The mill was then flushed out and a separation of coarse and fine material was made by hand picking out the coarse particles. The results were:

Wt. of coarse	- 8.250 Kg
Lead in coarse	- trace
Wt. of fines	- 3.164 kg
Lead in fines	- 0.326%

Total sample, per cent lead, calculated, 0.09%

It will be noted how effectively the scouring process removed the lead from the coarse pieces and threw it in with the fines. If it were found advantageous to use lead anodes, this scouring process could be done very easily.

Analysis of P-7 (Signal Corps)

Available Oxygen as MnO_2	89.3%
Total manganese	58.9%
Moisture	0.9%
Iron	0.02%
Silica	-
pH	4.8
Apparent density, grams per cubic inch	23.1
Lead	0.02%

Screen Analysis of P-7 (Signal Corps)

On 80-mesh	0%
On 100-mesh	0.2%
On 150-mesh	0.4%
On 200-mesh	2.2%
On 250-mesh	10.2%
On 325-mesh	63.0%
Through 325-mesh	24.0%

Capacity Test Data (Signal Corps)
(Test on cells prepared from P-7)

	High Drain Test	Low Drain Test
Average initial service	6.3 hours	130.3 hours
Minimum initial service (Signal Corps Specification)	5.5 hours	130 hours

MORPHOLOGY

Single Phase Gamma

A tabulation of the more important data from the small scale electrolyses is given in Table X and those from the pilot scale electrolyses are given in Table XI.

TABLE NO. I

RESULTS OF SMALL SCALE ELECTROLYSES

Sample No.	Cell	Solution	Cathodes	Anode	Cell Electrolyte H_2SO_4 g/l	Cell Electrolyte Mn g/l	Time	Temp.	Anode Current Density Amp/Sq. Ft.	Current Eff'cy. %	Cell Volts	Bulk Density Gm/cu in	pH	Morphology	Battery Test Low Drain Hrs. (Min.=130)	Battery Test High Drain Hrs. (Min.=5.5)	% Pb
S-1	4-L Beaker	$MnSO_4$ 100 g/l Mn	1" Rods Pure Lead Vicor Sleeve	1" Rod Pure Lead Vicor Sleeve	90	50	28 days	95°C.	5	103	2.3	29.3	7.0	---	----	---	0.084
S-2	4-L Beaker	$MnSO_4$ 100 g/l Mn	1" Rods Pure Lead Vicor Sleeve	1" Rod Vicor Sleeve Lead with 3.0 % Sb 0.5% Sn	90	50	28 days	95°C.	5	103	2.3	29.7	7.2	---	---	---	0.052
S-3	4-L Beaker	$MnSO_4$ 100 g/l Mn	1" Rods Pure Lead Vicor Sleeve	1" Rod Vicor Sleeve Lead with 7% Sb	90	50	14 days	95°C.	5	---	2.3	21.5	3.0	---	---	---	0.055
S-4	4-L Beaker	$MnSO_4$ 100 g/l Mn	1" Rods Pure Lead Vicor Sleeve	1" Rod Vicor Sleeve Lead with 1% Ag	90	50	28 days	95°C.	5	103	2.3	29.3	7.25	Alpha and Rho	132.7	6.8	0.032
S-5	4-L Beaker	$MnSO_4$ 209 g/l Mn	Copper	1" Rod Vicor Sleeve Lead with 1% Ag	283	50	24 hours	65°C.	45 reduced to 25	---	2.5	10	---	---	---	---	---
S-6	4-L Beaker	$MnSO_4$ 213 g/l Mn	Graphite	1" Rod Vicor Sleeve Lead with 1% Ag	335	85	10 days	65°C.	15	---	2.7	---	---	---	---	---	---
S-7	4-L Beaker	" $MnSO_4$	Graphite	Flat with Pyrex Sleeve 2" x 2" Lead with 1% Ag	90	50	23 days	95°C.	5	102	2.3	---	---	---	---	---	0.063
S-8	4-L Beaker	$MnSO_4$ 100 g/l Mn	Graphite	As S-7 but with Karbate Sleeve not cemented	90	50	23 days	95°C.	5	102	2.3	---	---	---	---	---	0.073
S-9	4-L Beaker	$MnSO_4$ 100 g/l Mn	Graphite	As S-7 but with Karbate Sleeve cemented with rubber	90	50	23 days	95°C.	5	102	2.3	---	---	---	---	---	0.073
(2) S-10	4-L Beaker	$MnSO_4$ 100 g/l Mn	Graphite	Same as S-9	90	50	23 days	95°C.	5	102	2.3	---	---	---	---	---	0.041

NOTES: * Deposit did not stick to anode, but sloughed off as a slime which settled to the bottom of the beaker

** The Karbate sleeves are not satisfactory, as they disintegrated below the solution line.

TABLE NO. XI

RESULTS OF PILOT SCALE ELECTROLYSES

Sample No.	Cell	Solution	Cathodes	Anode	Cell Electrolyte		Time	Temp.	Anode Current Density Amp/Sq. ft.	Current Eff'cy. %	Cell Volts	Bulk Density Gm/cu in	pH	Morphology	Battery Test		% Pb
					G/L H_2SO_4	G/L Mn									Low Drain Hrs. (Min.=130)	High Drain Hrs. (Min.=5.5	
P-1	40 Gal. Crock Micarta Cover	Prepared from Olympic Ore 98 G/L Mn	Made of 2-6 1/4" x 1-1/2" graphite slabs, 22-3/4" submerged	Same as Cathodes	40.6	75.0	5 days	95°C.	10.35	93	2.6	17.4	4.3	alpha, beta gamma (predominate)	100.4	6.3	0.02
P-2	Karbate Cell 7" x 14" cross section 36" deep Micarta Cover	Spent Electrolyte from P-1	Karbate Cell walls	Graphite 6-1/4" x 1-1/2" 31" submerged	80.0	52.0	12 days	95°C.	10.5	74	*2.9	18.3	4.0	predominate gamma minor beta	100.2	6.4	0.02
P-3	Karbate Cell as in P-2	Fertilizer grade $MnSO_4$ purified	Karbate Cell walls	As in P-2	40.0	78.0	3 days 5 hours	95°C.	15.0	83.08	*2.93	17.4	4.2	Single phase gamma	107.2	6.0	0.02
P-4	Karbate Cell as in P-2	Tasmanian ore solution 1 and 2	Karbate Cell walls	As in P-2	90.0	60.0	14 days	95°C.	15.0	70.0	*3.3	14.3	3.9	alpha, (predominate) beta gamma	107.0	6.3	0.02
P-5	Karbate Cell as in P-2	Tasmanian ore solution	Karbate Cell walls	1% Ag-Pb Rod. Vicor glass sleeve 26" submerged	97.0	55.0	21 days	95°C.	15 and higher	41	*3.5	---	---	---	---	---	1+
P-6	Karbate Cell as in P-2	Tasmanian ore solution	Karbate Cell walls	Graphite as in P-2	87.5	50.0	15 days	95°C.	7.5	91	*3.0	24.8	4.1	Single phase gamma	143.8	7.3	0.02
P-7	Karbate Cell as in P-2	Tasmanian ore solution	Karbate Cell walls	1% Ag-Pb Flat oval 4" wide 3/8" thick at center. Karbate sleeve 28" submerged	89.0	48.0	28 days	95°C.	7.5	89.0	2.5	23.1	4.8	Single phase gamma	130.3	6.3	**0.02

NOTES: * High voltage undoubtedly due to poor contact to Karbate cell cathode.

** Lead reported by Signal Corps on scoured sample. The material as stripped contained 0.09% lead.

CONCLUSION

Two types of manganese ore were successfully treated. They were Olympic Peninsula bementite ore and a typical pyrolusite from Tasmania. The Olympic ore was the more difficult to treat because of its combined silica, making the reduction roasting, leaching, and filtration somewhat difficult. No trouble was had with the Tasmanian pyrolusite.

Both types of ore required a reducing roast to transform the higher valence states of manganese to the sulfuric acid soluble bivalent state. Sawdust in the form of "Pres-to-Logs" pellets was used as a reducing agent. It was found that roasting for one hour at 700°C. with 15 per cent sawdust would satisfactorily reduce the 48 per cent Tasmanian ore.

Leaching of the calcine from the Olympic ore as well as that from the Tasmanian ore was accomplished by a process known as "reverse leaching." This consists of pulping the ore with enough solution to permit agitation, then adding the acid gradually while trying to avoid ever having an excess of acid. By this method of leaching, the dissolution of iron, silica, and alumina can be partially avoided; and at the time of the final neutralization, they are not thrown out of solution as difficulty filterable gels. Ferrous iron was oxidized by the addition of ground pyrolusite or raw ore to the leach prior to final neutralization. Thus, the leach and iron purification were made in one step.

The best leach recovery for the Olympic ore was 78.7 per cent, and 90 per cent was attainable using the Tasmanian ore. Filtration varied from leach to leach, and it is believed that conditions promoting filterability could be more definitely determined by additional research.

Solutions from leaching calcine from the Olympic ore was sufficiently pure for electrolysis, but that from the Tasmanian ore was purified by the addition of barium sulfide to the filtered leach solution.

Electrolytic experiments were carried on in order to determine conditions necessary for the production of the desired gamma phase manganese dioxide of sufficient purity and bulk density to satisfy the Signal Corps Specifications.

The use of lead anodes as well as the usual graphite was investigated, and a satisfactory product was made on each.

Cathodes of graphite, lead, and copper were tried out in small scale (4-liter beaker cells) electrolytic tests and were all found to be satisfactory. However, copper is not recommended because of insufficient testing. If lead cathodes were used, they should be protected at and above the solution line by covering with some inert substance. Casting the lead stems through Vicor glass proved satisfactory except for breakage. Judging by observation of the effects of the comparatively short runs made, neither lead nor graphite are appreciably corroded when used as cathodes.

The following conditions are recommended as favorable for the production of a satisfactory gamma phase manganese dioxide. It is not to be inferred, however, that these are the only satisfactory conditions, as there are many combinations of variables which were not tried.

Temperature of electrolysis	- 95°C.
Electrolyte, H_2SO_4 content	- 90 - 100 grams per liter
Manganese content	- 40 - 50 grams
Current Density	- 7.5 amperes per square foot

With the above conditions, current efficiencies of 89 per cent or better were obtained, and cell voltages varied between 2.3 and 3.0 volts. It is believed that the higher voltages were caused by poor contacts, and that the voltages should not have gone above 2.5 volts.

Where lead anodes are used, the following precautions should be taken:

(a) It is believed that cylindrical rod anodes are better than anodes with flat surfaces because when rods are used the manganese dioxide can be deposited completely around the rod, and the deposit is not so likely to spring loose.

(b) The anodes should be pointed or wedge shaped at the bottoms to cause them to shed any bubbles which may form. It has been noticed that where bubbles form on horizontal surfaces at the bottom of anodes they stick and act as spots of insulation, and the deposit builds up around the bubbles. This makes a honeycomb effect with holes extending from the surface of the deposit clear through to the anode surface itself. It is believed that such an effect weakens the protecting envelope of manganese dioxide and may permit electrolytic action to take place behind the deposit, causing excessive anode corrosion.

(c) This work indicates that a lead alloy containing 1 to 2 per cent of silver is less subject to corrosion than pure lead or other lead alloys.

(d) Lead anodes should be protected from corrosion at and above the solution line by placing sleeves of some inert material around the stems by which the anodes are suspended. Any glass, ceramic, or plastic, which is not corroded by 10 per cent sulfuric acid at 95°C., would be satisfactory. Vicor glass tubes with the lead cast through them were satisfactory except for the fact that it was difficult to strip off the manganese dioxide without breaking the glass. A plastic capable of withstanding the severe conditions would be desirable.

(e) Lead can be largely eliminated from a manganese dioxide made on a lead anode by tumbling the stripped deposit with water in a revolving drum. The abrasion of the particles against each other scours off the surfaces of the slabs, and since the lead is nearly all concentrated at the inner surface where the deposit was in contact with the lead anode, the abraded fine material contains most of the lead. A simple screening or desliming will remove the lead along with a small portion of the manganese dioxide.

Senator MALONE. Bruce Irwin, Colorado School of Mines Research Foundation.

Mr. Irwin, you are from the Colorado School of Mines?

Mr. IRWIN. That's correct, sir.

Senator MALONE. Will you identify yourself for the benefit of the subcommittee and just proceed in your own way and give the committee the benefit of any advice or counsel or information that you think might be helpful.

STATEMENT OF BRUCE IRWIN, COLORADO SCHOOL OF MINES RESEARCH FOUNDATION, GOLDEN, COLO.

Mr. IRWIN. My name is Bruce Irwin. I am representing the director of the Colorado School of Mines Research Foundation, located at Golden. In the remarks I would like to make here, we have presented a memorandum here which I would like to just cover very briefly to conserve your time, and at such time in the future as we can review our notes we can expand on that, if that is acceptable to you.

Senator MALONE. You can review your testimony and just submit it to the record, and then it will be transmitted to you for your review for completeness and accuracy.

Mr. IRWIN. So I will just follow the memorandum through, and I should identify the fact that the research foundation is a nonprofit incorporated foundation whose activities are restricted entirely to mineral industry research. The director of the foundation is Mr. Vernon Matson, a well-known mining authority in the country. The observations I would like to make pertain particularly to projects which we have handled and done some work on the past several years, and what we do know about these things may be in a preliminary form, or in a more extended form, but the recommendations we would like to make pertain to problems that look to us need research, either by ourselves or by other competent research teams, and they suppose the condition that they appear very likely of concrete results for a minimum expenditure of research funds.

Senator MALONE. Let me ask you at this time, who is the director of your mine school now?

Mr. IRWIN. Vernon Matson, Vernon L. Matson.

Senator MALONE. He is the same man that leads this research?

Mr. IRWIN. That is right.

Senator MALONE. Who is the former director?

Mr. IRWIN. The foundation was created some 4 years ago to take over the work of the experimental plant of the Colorado School of Mines, formerly headed by A. J. Weinig.

Senator MALONE. That still isn't the man.

Mr. IRWIN. It is about 4 years old as it stands today. Mr. Vanderwilt is—Dr. Vanderwilt is the president of the Colorado School of Mines.

Senator MALONE. Who was the former president?

Mr. IRWIN. Mr. Ben Parker. Dr. Koolbaugh also.

Senator MALONE. That's right. Is he still there?

Mr. IRWIN. No, Dr. Koolbaugh is dead, and he retired some years ago. His position was taken by Mr. Parker, Dr. Parker I should say, and subsequently Dr. Vanderwilt is now heading the school.

Senator MALONE. I do not know personally the men you mention, but Dr. Koolbaugh helped us in this industrial encyclopedia preparation of the 11 Western States in 1938, 1939, and 1940, and I have a very high regard for him.

Mr. IRWIN. We all do in the industry, even though he has been gone a number of years. A lot of his work was pioneering things that we are getting into today.

Senator MALONE. He had character and imagination and all it took to build a school of mines, yes.

BERYL AND BERYLLIUM

Mr. IRWIN. One of the little problems that we would like to bring your attention to briefly is the problem of beryl and beryllium. The problems that we feel require study pertain principally to the recovery of beryl in this country. Presently your beryl is of a massive variety, and in general, as a result of hand-picking ore, hand-selecting methods, it is a coarse product. By far and large, the greater proportion of the finely disseminated beryl ores are neglected, and more or less considered are not reserves of that material. Present thought along this line, as well as certain experimental work, indicates that a very potential opportunity exists in the concentration by froth flotation of fine grained, finely disseminated beryllium-bearing material, principally beryl. Finer beryl ores today are either wasted or neglected.

A second point along this line of beryllium is the review in our mineral resources of beryllium-bearing minerals that have been more or less neglected; for instance, in the State of New Mexico near Iron Mountain there is a very extensive deposit of low-grade beryllium-bearing ore, it is called. The mineral involved is not beryl but a mineral called helvite, which is a beryllium manganese, silicated, largely neglected because of its low-grade character and the proximity of adequate beryl ores, beryl production in the country.

We feel that a certain amount of research in connection with helvite or crystal beryl as to reserves of those materials would give us a better picture of what we have got in the order of low-grade ores. On top of that, the research necessary to beneficiate these materials does not constitute, as far as we can see, a problem that can't be resolved quite readily by a reasonable amount of research.

One of the problems, as far as we can see, that is holding back beryl and the discovery of beryllium deposits is the analytical situation, the detection and anaylsis of beryllium materials. It may not be well known to you, but there are not very many laboratories in this country that will take on a beryllium analysis; the wet analysis for higher-grade materials is considered quite toxic, and most analysts and analytical laboratories are very reluctant at any time, and charge rather high prices for such beryllium analyses that are made. We need in this instance a program of research that will allow us easier detection and analytical methods in connection with beryllium and its components. Present methods are not adequate whatsoever for production methods. We have done some work along that line, a number of ideas which I will be glad to expand on later.

DIAMOND SLUDGE PROBLEM

Another problem that has been of interest to us over a period of the last few years is the diamond sludge problem. As it stands today, your diamond sludge buyers are very picayunish about what they will take, and they take only the cream of the diamond sludge products that are available; consequently, a great portion of diamond sludge material that might ordinarily be available is put in 55-gallon drums and put away for the day when it can be resolved. On top of it, your diamond sludge buyers are making a lucrative living.

The problem as we see it in research and as we are attacking it today is the recovery of diamonds from this sludge that presently is not being recovered.

As far as normal treatment methods, our work indicates that normal or dressing techniques can be modified to satisfy this requirement, and we feel that with the development of these techniques a greater quantity of diamond sludge material will be made available to the market.

Another problem is the analysis, analytical method required for diamond sludge. As it stands today, the seller has no alternative but to accept the analysis of the buyer, a very nice situation, and analytical research in connection with diamonds in diamond sludge is certainly required at this time.

KYANITE RESEARCH

Dipping into the next problem here, which involves your kyanite problem, as we call it, the last war set up more or less the situation that resulted in the development of your so-called synthetic mullite. We couldn't get India kyanite, so we had to develop a substitute. The industry requires a comparatively coarse kyanite material. They crush that material suitably to satisfy their requirements and use it as such. Now, the synthetic kyanite satisfies that requirement in being coarse. Today in quite a number of our operating mills in the East we are handling kyanite every day, but the situation is that it is a fine-grained material, unsuited to the refractory manufacturer as it stands.

The research problem as we see it today involves the reagglomeration of that material, very similar to the taconite problem they have of very fine-grained concentrates being agglomerated in such a form as to make blast-furnace material.

The problem as we see it, then, is research in connection with the reagglomeration of fine-grained kyanites; the recovery of kyanite in a fine form is known. Samples are available. A number of mills are actually in position to produce it tomorrow if you asked for it. The refining of the kyanite suitable for refractory people would be the problem as we see it here today.

NEED FOR REEVALUATION OF MICA PROJECT

Another problem which has been discussed by Dr. Aitkenhead is the mica problem. The initial work on that project was conducted at the School of Mines prior to the formation of the Research Foundation. However, in the intervening years we followed the research of

the Bureau of Standards and the Bureau of Mines, and we have considered that problem very seriously as to what future course of action should be. We feel at this point that the Bureau of Standards in its platinum vessels and its use of platinum vessels in the furnace equipment has not hit the actual problem that we are looking for, which is the formation of large flake-form mica.

The Bureau of Mines in its work, using graphite crucibles, has come up with graphite—suitably large crystals, however, contaminated with enough carbon to make them unsuited for electrical work. Mr. Ralston can probably give us a better picture of that than I at this point.

We feel at this time that the reevaluation of this project should be considered by those that are interested in synthetic mica, to incorporate some of the findings that Dr. Aitkenhead has brought into this project, at the initial stages here, and that the use of a crucible form of phlogopite mica and its constituents, which you would use for synthetic mica, constitutes a basis for a suitable crucible for the development of large flake mica, large-diameter flake mica.

RARE EARTH MINERALS

Another problem as we see it is the rare earth minerals. The mineral thorite, for instance, or the mineral hydrothorite have been largely neglected because of the proximity of monazite sands and so forth. Considerable thorite and hydrothorite exist in this country and there has been very little research conducted in the recovery of those minerals. In the event of a problem as far as monazite, we feel that thorite research would be more or less stockpiling research and would provide a background that we may need in the future production of thorite or thorium and other related materials.

MISCELLANEOUS MINERAL PROBLEMS

In the area of miscellaneous problems, of course, we have covered a number of these things already in previous testimony: manganese, we feel at this time and we know of research that has been conducted in the recovery of manganese from furnace slags.

In the field of domestic chrome ore, our own studies in that indicate, as indicated by a previous witness here, that the improvement of the chrome to iron ratio can only be conducted and can be successfully conducted by chemical means.

Some work on Montana chromites has indicated that to us as being a very feasible research project that would net results with a minimum of research mining.

We have studied the laterite cobalt-nickel ores of Cuba and also of the Sudbury district, and we feel at this time, studying these materials and doing certain preliminary work, that chemical methods pose a very potential solution to those problems. The laterite ores are very widely distributed throughout the world, and the proximity of those ores to our own country is very close.

Tungsten as we see it today has been in a research vacuum here for about 14 years. The most recent technological development has been at the Bishop Plant, United States Vanadium Co., which I believe

was started in 1940. During this period of 14 years there has been nothing developed as far as new techniques or new processes for the recovery of tungsten. We have been in a research void as far as tungsten is concerned.

I wanted to mention one little deposit that exists in our own State; near Winnemucca there is a deposit which is known as the Golconda deposit. The urgency of World War II brought that deposit into attention. Certain work was done in the laboratory. It was translated immediately from a batch-scale proportion to a full-scale plant, and with subsequent failure of the plant to operate, the plant has now been thrown to the winds and the deposit stands as it is, a very extensive and attractive proposition, yet, as far as we can see, somewhat of a metallurgical riddle. Work that we have conducted and tungsten authorities who are employed by the foundation feel at this time that the Golconda deposit is well within the reach, as far as a workable tungsten operation, with a minimum of research in connection with its extraction.

There is one other point that isn't in the memorandum, but it pertains particularly to the operations of our oil industries. In Wyoming, in Colorado, new oil deposits are being found every day. Along with the oil doposits come your reformers, cracking plants, and so forth. The byproducts of these plants——

Senator MALONE (interposing). Lewellyn, Nev.

Mr. IRWIN. The byproduct of these products being hydrogen; the byproduct, of course, that I am interested in is the gas hydrogen, for which there is no use except to burn, in order to keep it from being a hazard to the countryside at large. Hydrogen, as such, in large amounts, in a situation of being practically a waste product, poses a very great potential, we believe, to hydrogen reduction of certain metals in the West. There are quite a number of metals that are reducible by hydrogen. There are quite a number of metals in the West close by to these locations that are available, so that the potentiality of hydrogen reduction metallurgical plants to us seems a considerable problem as far as the future is concerned in western metallurgy. That might pertain particularly to Wyoming ilmanite as well as Idaho ilmanite where smelting costs would be excessive, or to send it to the East, whereas smelted metal might pose an entirely different problem.

I think that more or less concludes my remarks as I would like to make them here, and if there are any questions I would be glad to answer them.

Senator MALONE. What is the extent of the field, the area that you cover generally in your research foundation at the Colorado School of Mines?

Mr. IRWIN. The research foundation, as such, is concerned with a step between the batch laboratory and the finished operating plant. By that I mean our main interest is pilot plant scale operations. We do batch laboratory work, as many universities and other experimental stations do. Our concern is the scaling up from a thousand grams to maybe a hundred tons on a daily operation, the intermediate step between laboratory study, test tubes, and actual production.

Our staff in general is composed of very practically minded individuals. The operating point of view is the most important part, as far as we are concerned.

Senator MALONE. Your objective is economic production?

Mr. IRWIN. If it isn't economic, we cannot find the sponsored research to support us. It has to be a product that will pay or will pay off. We do considerable preliminary work to establish that point, whether it will pay or whether it will not. I think that is one of the principal areas that we cover.

Another area is the survey of situations in metals; for instance, in tungsten or beryllium or some of these other metals I have mentioned, economic surveys, market surveys, to see whether an industry, a particular company can exist in the economic area that they would like to start out on, whether they should wait or whether it is pertinent to get in right now. We do a great deal of work in potash.

Senator MALONE. That is very interesting, and the subcommittee is interested in your testimony, because it is mainly in a strategic, critical field. Now, your State is right in the middle of the production and the search for uranium ore. There is a project at the University of Nevada in the search for new and improved methods of beneficiating uranium ore. Of course, you are right in the middle of this research, you know the difference between country rock and ore is just a different method or lower cost method of beneficiating it. I am informed by Professor Schied, who is the head of our school of mines, that he has some very interesting ideas now that seem to have promise of working out. I hope so. We believe, at least the subcommittee came to the conclusion after hearing testimony in Salt Lake City from Colorado and Utah mining men, Nevada, Wyoming, that if our taxpayers were treated half as well as the foreign producers, you would probably have uranium running out of your ears in a couple of years. No mystery about it any more. And vanadium, which we used to think was so scarce, is actually, has actually become a byproduct of uranium and is running out of our ears. So times change. The economics of the material determines its future. That is nothing new. It has since time began, or since we began to make use of these materials.

This new metal, titanium, I don't know whether you have noticed it at all or not, but they are perfecting the Kroll process. Several companies believe, at least two large companies believe they may have shortcuts to skip the sponge, which, if they do, would be an immediate step in the direction of lowering the price. All of these things are so interesting.

We will return your manuscript to you, your testimony, and if you would care to, you could have any meeting or consultation that you care to have. What we would like to have from you then in your testimony is just as many of these materials, critical materials that you think your research has the earmarks of either cheapening the production, reduction, making more ore available, that is to say, turning some of the country rock into ore, and on substitutes or replacements or in that field of critical materials; and you have a wide latitude in editing your testimony for accuracy and completeness, and if you care to, we can just make this written statement a part of the record at this time to supplement your testimony.

Mr. IRWIN. I would very much like to expand that, and we will do so.

Senator MALONE. Thank you, and if you could give us any references of other colleagues or foundations and persons that are interested

in the same work or a different work and a description of the field, if you will do that it will be very helpful.

Mr. IRWIN. Yes, sir.

Senator MALONE. The subcommittee came here for a specific purpose, and that is to pursue, under Senate Resolution 271 extending the work of the subcommitte, to lay a foundation for the year's work that started, as we did in Seattle last year, with particular reference to the synthetics and to replacements and substitutes, and to round out the field.

STATEMENT OF RAYMOND EWELL, SECRETARY, NATIONAL SCIENCE FOUNDATION, WASHINGTON, D. C.

Senator MALONE. Mr. Ewell, would you proceed in your own way and give us any information that would be beneficial to the subcommittee. I understand that you do have either a directory or a comprehensive outline of the research projects in the United States.

Mr. EWELL. We do.

Senator MALONE. You go right ahead.

Mr. EWELL. My name is Raymond Ewell. I am the Assistant Director for Program Analysis of the National Science Foundation, an agency of the Federal Government, in Washington, D. C. I would like to put into the record, Senator Malone, that I am not only a chemical engineer, but also an economist. I have earned my living professionally for 18 years as a chemist and chemical engineer, and for 8 years as an economist, so I see both sides of the coin.

Senator MALONE. That ought to be very helpful.

Mr. EWELL. We have at the National Science Foundation and specifically in my office the most complete collection of statistics and other sources of information relating to research in the United States that is available anywhere, and we will have a great deal more as a result of studies we are now conducting at the National Science Foundation.

The testimony that I wanted to present is concerned entirely with the subject of research. I have five principal points that I would like to make. One is the importance of basic research in any broad program of research, such as the one that your recommendation No. 11 proposes for critical materials. The second point, which I will go into a little more detail, the present program of the National Science Foundation in basic research as it relates to these critical materials. The third point regards the activities of the National Science Foundation's Committee on Mineral Research. I wasn't sure whether you were familiar with that organization or not. The fourth point concerns the status of research on synthetic and substitute materials, particularly in industry, and the fifth point is the scientific manpower problem which Representative Hinshaw so ably presented before the American Legion a few weeks ago in Washington.

IMPORTANCE OF BASIC RESEARCH

To take up first the importance of basic research, applied research, of course, is the real heart and payoff of any research program, particularly a very broad program such as you are proposing on the critical materials problem. Intelligent applied research, aimed at

specific problems, certainly pays big dividends. It is a creator of wealth, and turns uneconomic materials into economic materials. However, I wanted to bring out the importance of allocating some of the research effort to basic research, which experience has shown will yield better results in the long run than a purely applied research program.

In a broad program such as recommendation 11 proposes, it wouldn't be amiss to think in terms of about 10 percent of the total effort being devoted to basic research to get the most results in the long run. That figure of 10 percent is one just pulled out of the air, but I might substantiate it this way. A recent survey published by Harvard University showed that American industry in general, the whole American industry, does about 8 percent of its research in the field of basic research. The chemical industry, which is one of the more research-minded and progressive industries, devotes 14 percent of its research effort to basic research. The Du Pont Co. alone, which is well known as a progressive company, devotes 20 percent of its research efforts to basic research. The particular figures in the case of the Du Pont Co. are that they are this year expending $65 million on research, out of which $13 million is basic research, a great deal of money for a private source to put into basic research. Parenthetically, I might mention that of all the American industries, the primary metals industry devotes the smallest percentage of its research effort to basic research, namely, 1.7 percent as compared with the chemical industry, for instance, at 14 percent.

The National Science Foundation, as you, Senator Malone, are undoubtedly aware, supports basic research in many different fields, particularly the basic branches of science, chemistry, physics, engineering, biology, medicine, and so on. A great many of the basic research studies that we are now financing in the universities do relate to the critical materials problem; studies in physics and chemistry, and of course most specifically those in geology, and geophysics and geochemistry.

I might mention just a few specific titles to illustrate that some of our support is pointed toward the critical materials problem. One is called igneous geology in the Beartooth Mountain area in Wyoming and Montana; another one is called, isotopic abundances and other problems relating to geochemical research. Another one is hydrothermal alteration studies of micas, micalike clays and related minerals; another is research in the geochemistry of quicksilver ores.

Last year, last fiscal year, we put $282,000 into basic studies in the earth sciences, principally geology, geophysics, and geochemistry. In the current fiscal year the budget is something in the order of $500,000.

Now, the next item that I wanted to mention was the fact that the foundation has a Committee on Minerals Research which was appointed by the National Science Board in 1952, as a direct result of one of the recommendations in the Paley report that the National Science Foundation should undertake to develop basic research relating to the discovery and extraction of minerals. The National Science Board appointed this Committee on Minerals Research, which has 18 members.

Senator MALONE. Would you mind putting a list of those members into the record?

Mr. EWELL. Yes; I will.

(The material referred to follows:)

COMMITTEE ON MINERALS RESEARCH

Allen V. Astin, National Bureau of Standards, Washington, D. C.
John G. Bartram, Stanolind Oil & Gas Co., Tulsa, Okla.
Alan M. Bateman, Yale University, New Haven, Conn.
James Boyd (chairman), Kennecott Copper Co., New York, N. Y.
Arthur H. Bunker, Climax Molybdenum Co., New York, N. Y.
Gordon L. Davis, Geophysical Laboratory, 2801 Upton Street, Washington, D. C.
W. Maurice Ewing, Lamont Geological Observatory, Torrey Cliff, Palisades, N. Y.
Paul D. Foote, Gulf Research & Development Co., Pittsburgh, Pa.
Louis C. Graton, 182 Brattle Street, Cambridge, Mass.
John K. Gustafson, M. A. Hanna Co., Cleveland, Ohio.
C. K. Leith, National Research Council, Washington, D. C.
Thomas B. Nolan, United States Geological Survey, Washington, D. C.
William W. Rubey, United States Geological Survey, Washington, D. C.
Louis B. Slichter, University of California, Los Angeles, Calif.
John W. Vanderwilt, Colorado School of Mines, Golden, Colo.
Clyde E. Williams, Battelle Memorial Institute, Columbus, Ohio
William Wrather, United States Geological Survey, Washington, D. C.
Paul Zinner, Minerals Division, Bureau of Mines, New Interior Building, Washington, D. C.

SUBCOMMITTEE ON GEOCHEMISTRY

R. M. Garrels (chairman), United States Geological Survey, Washington, D. C.
Earl Ingerson, United States Geological Survey, Washington, D. C.
Konrad Krauskopf, Department of Geology, Stanford University, Palo Alto, Calif.
J. L. Kulp, Columbia University, New York, N. Y.
T. S. Lovering, United States Geological Survey, Denver Federal Center, Denver, Colo.
Edwin Roedder, University of Utah, Salt Lake City, Utah.

SUBCOMMITTEE ON GEOLOGY

C. A. Anderson, United States Geological Survey, Washington, D. C.
Charles H. Behre, Jr., Columbia University, New York, N. Y.
A. F. Buddington, Princeton University, Princeton, N. J.
W. S. Burbank, United States Geological Survey, Washington, D. C.
Carl E. Dutton, United States Geological Survey, Madison, Wis.
R. N. Hunt, United States Smelting, Refining Co., P. O. Box 1980, Salt Lake City, Utah.
Thomas S. Lovering, United States Geological Survey, Denver Federal Center, Denver, Colo.
Hugh E. McKinstry, Harvard University, Cambridge, Mass.
Charles Meyer, Department of Geological Sciences, University of California, Berkeley 4, Calif.
Thomas G. Moore, Geology and Exploration Department, American Metal Co., Ltd., 61 Broadway, New York, N. Y.
James A. Noble, California Institute of Technology, Pasadena, Calif.
V. D. Perry, Anaconda Copper Mining Co., Salt Lake City, Utah.
G. M. Schwartz, University of Minnesota, Minneapolis, Minn.
F. S. Turneaure, chairman, University of Michigan, Ann Arbor, Mich.

SUBCOMMITTEE ON GEOPHYSICS

J. R. Balsley, Geophysics Branch, United States Geological Survey, Department of the Interior, Washington, D. C.
A. F. Birch, Harvard University, Cambridge, Mass.
Arthur A. Brant, Newmont Exploration Ltd., Box 366, Jerome, Ariz.
Henry Faul, United States Geological Survey, Washington, D. C.
Sigmund Hammer, Gulf Research and Development Co., Pittsburgh, Pa.
C. A. Heiland, Heiland Research Corp., 130 E. Fifth Avenue, Denver, Colo.
B. F. Howell, Jr., chairman, Pennsylvania State University, State College, Pa.
Patrick M. Hurley, Massachusetts Institute of Technology, Cambridge, Mass.
J. A. Noble, California Institute of Technology, Pasadena, Calif.

SUBCOMMITTEE ON MANPOWER

Charles B. Hunt, American Geological Institute, National Research Council, Washington, D. C.
Howard A. Meyerhoff, chairman, Scientific Manpower Commission, 1530 P Street, Washington, D. C.

Mr. EWELL. I will just mention now that the chairman is James Boyd of Kennecott Copper Co., well known in all mining circles. Several other industry members are John Bartram of the Stanolind Oil & Gas, Arthur Bunker of Climax Molybdenum, Paul Foote of Gulf Oil Co., John Gustafson of M. A. Hanna Co., and there are other members, totaling 18. This committee has had several meetings and has set up four subcommittees: a subcommittee on geology, a subcommittee on geophysics, a subcommittee on geochemistry, and a scientific manpower subcommittee. They are now preparing a number of quite far-reaching recommendations in the field of research relating to discovery and extraction of minerals. One of these recommendations may call for the establishment of an Institute for Minerals Research to conduct basic research in all the fields of science relating to the discovery and extraction of minerals, in fact, the entire area of minerals and geology.

Mr. ADLERMAN. How are the other institutes financed?

Mr. EWELL. Which ones?

Mr. ADLERMAN. You mentioned that there were four other subcommittees there.

Mr. EWELL. Yes, there are four subcommittees, but this Institute for Minerals Research would be one of the recommendations of the whole committee.

Mr. ADLERMAN. Do they have any other institutes of research?

Mr. EWELL. Well, this institute, presumably, would be a somewhat different organization than any other in the country. There are, of course, many institutes of research in the country.

Mr. ADLERMAN. Is it contemplated that this institute would be under Government auspices or receive Government funds?

Mr. EWELL. The basic idea is that the Government might assist it in getting started, but that thereafter it is hoped it could receive its support from industrial sources.

Mr. ADLERMAN. I didn't mean to interrupt you.

Mr. EWELL. As I said, the ways and means of doing this haven't been entirely worked out yet, but Jim Boyd and the other industry people on the committee hope, at least, that something can be worked out.

RESEARCH ON SYNTHETIC AND SUBSTITUTE MATERIALS

Now, in the field of research on synthetic and substitute materials, it is my personal opinion as an observer that private industry is doing an outstanding job in this field, particularly the chemical industry and allied industries. The chemical industry has been outstanding in developing synthetic plastics, synthetic fibers, synthetic rubbers, synthetic drugs, and many other synthetic materials which are either exact reproductions of natural materials, or they are different, but substitutes which are just as good and in many cases better.

Mr. ADLERMAN. Do any of these substitutes or synthetics define themselves as strategic materials?

Mr. EWELL. Well, they cover the entire gamut of strategic and consumer products.

Mr. ADLERMAN. Would you give us some illustration of where they take the place of strategic materials?

Mr. EWELL. I was going to mention, for instance, the broad range of products that plastics replace or very directly compete with, you can go into any store like Macy's and see examples. Plastics replace iron, steel, copper, lead, zinc, tin, nickel, cadmium, aluminum, magnesium, wood, rubber, leather, glass, ceramics, paper, and textiles. You can go to Macy's store and see 10 examples of every one of these. In many cases they do a better job; in some cases they do as good a job, but they are cheaper, and therefore, they are economic. Of course, industry's motives in all of the vast amount of research that is done on these various synthetic products are strictly economic. Their motives are strictly nonstrategic motives, are entirely economic, and pay off in the form of profits.

Just focusing attention for a minute on the replacement of metals by plastics, metals have a great many properties, but there are several properties that are pretty common to most metals; they have electrical conductivity, thermal conductivity, they have fairly good resistance to high temperatures, depending on the metal, they have corrosion resistance, some of them do and some don't, and they have high strengths. That, of course, varies with the metal.

Now, there are 5 or 6 properties that are characteristic of metals and uncharacteristic of most other substances. Plastics, of course, are not applicable where electrical conductivity is concerned or thermal conductivity or resistance to high temperatures, but in the field of corrosion resistance and moderate strength, plastics are extremely good, and those two qualities, corrosion resistance and a fair amount of strength, are the principal uses in which plastics replace metals. Their cheapness of fabrication is a further economic factor; superimposed on that there are some that are fairly heat resistant, too. One of the outstanding plastics in replacing metal in very key uses is nylon. You can mould the most beautiful little gears out of nylon that will do everything a metal gear will and last longer, and nylon is one of the higher temperature plastics that can stand temperatures of 350° to 400° F., something of that order.

Mr. ADLERMAN. There has been some talk of a plastic wing for sonic speed planes which would be heat resistant.

Mr. EWELL. Of course, that would be one of the glass fiber and polyester combinations, like they make these 35-foot boats out of.

Mr. ADLERMAN. So there are some?

Mr. EWELL. Yes, they have a reasonable heat resistance.

One of the interesting replacements of metals by plastics is in the pipe field. Many of the uses of pipe do not require any particular strength. Just take for instance the copper pipes used in the cement floor of radiant heated houses. Pressures involved are fairly low, and it is embedded in concrete, anyway, so the plastic pipe can replace that use; right now, it is mainly made out of copper. Plastic is coming into that field, and there is a lot of pure copper going into that use that could go into electrical applications in case copper was short. In fact, I heard a statement recently that plastics would probably ultimately replace something like 10 percent of all the pipe used in the country, it is probably on the order of 1 percent now.

Well, this question of replacements and substitutions goes on and on. One little one, for instance, is the replacement of mercury in fungicides. One of the biggest uses of mercury is in agricultural fungicides, and mercury does a good job there, but it is not the only thing that will kill fungi. They are making a synthetic organic product that has no mercury in it at all that will do nearly as good a job.

NEED FOR TRAINING FUTURE SCIENTISTS

Well, we could go on all afternoon on this subject, so we will just stop at that point. The last point I wanted to talk about is the scientific manpower problem. As the Nation's problems multiply due to shortages, military requirements and other factors, we are going to need more and more research, and in the normal course of economic development we will need more and more research. Many people in Washington are looking at the scientific manpower problem, trying to balance supply and demand estimates for future years: There is a great deal of disagreement on how to estimate supply and demand, but almost everybody agrees that the shortage will probably get worse and that within a few years, 1958, certainly by 1960, the shortage of scientists in the United States may be a national problem. It will be a national problem from two standpoints: internally and externally. The internal problem is that unless there is some change in the probable flow of scientists, we may not have enough scientists to maintain our past economic growth rate. This does not mean that we will have a lower level of economy than we have now, but the United States has become accustomed to a 3 percent per year average economic growth rate, and if we do not have enough scientists and engineers the growth rate may fall below 3 percent. That is probably not as pressing as the external problem, on which data have come to light within the past 8 or 9 months, that the Russians may be approximately even with us now in the number of working research scientists and engineers. They might even be a little ahead of us, but within the errors of estimation on both sides, we have about the same number of research scientists and engineers working in the laboratories. However, right today the Russians' production rate of new scientists and engineers is approximately twice as great as ours.

Mr. ADLERMAN. Did you say twice as great?

Mr. EWELL. Twice as great, yes. There is a great deal of variation on that figure, too. Some people even say two and a half times. Just for example, here are some figures, that during the past school year we graduated about 30,000 scientists and engineers at the batchelor's level, and the Russians graduated somewhere between 60,000 and 75,000. Not all of those go into research, of course; they go into production also.

Mr. ADLERMAN. I would just like you to repeat that last there about the ratio between the United States and Russia for the benefit of the Senator, if you don't mind repeating that part of the testimony.

Mr. EWELL. Yes. We had just gotten around to the point I was going to talk about, Senator Malone, on the scientific manpower problem, that we have a shortage of scientific manpower at the present time. A few Members of Congress are beginning to become aware of this and I think more and more Members of Congress will become

aware of it: that within a few years, probably within 3 or 4, and not later than 1960, the shortage of scientists may be one of our foremost national problems. We may not have enough scientists on hand to maintain our economic growth that we are accustomed to, and, even worse, we may wind up with fewer scientists on duty than the Russians have. The number of research scientists in Russia today is approximately the same as ours. There are around 200,000 research scientists and engineers in each country. On the Ph. D. level and bachelor's level both, they are about equal.

Senator MALONE. Do you mean that the country might come to appreciate engineers and scientists, finally?

Mr. EWELL. Well, we scientists and engineers think that their activities create a great deal of wealth.

Senator MALONE. I am interested in what you say. What causes the shortage, why is it that the professions such as engineering and science and research are no longer too interesting for the younger people of the Nation?

Mr. EWELL. Before I go into that, I would like to point out while we are about it, that while we are about even with the scientists in total number right now, the Russians are substantially ahead of us in the rate of production. During the past school year the Russians produced somewhere between two and two and a half times as many graduates in science and engineering as we did.

Mr. ADLERMAN. The difference between our levels was 30,000 that we produced and they produced 60,000.

Mr. EWELL. Sixty to seven-five thousand, different estimates.

Senator MALONE. Let me ask you this question: Are they produced on the same level of education?

Mr. EWELL. Yes. Of course, data are meager on the quality of Russian graduates compared to ours.

Senator MALONE. That is what I mean.

Mr. EWELL. But in the field of mathematics and physics, at least the people that know a little about it seem to think the quality is about the same. In mathematics their quality might even be higher than ours. Now, the Russians are able to produce more scientists and engineers than we are because they started it, actually, back in the 1930's. They were in abeyance during the war, but right after the war they started right in again, systematically combing through the entire youth of the Nation around 15 to 18 years of age, picking out the highest intelligence students, and sending them to college. There was no question about it, they went to college. The Government paid for it. Moreover, they have a much higher percentage studying science than we do. That is, of these bright kids that go to college about 60 percent of them go into science, whereas, in the United States, it is up to each student to pick his own field, and about 30 percent go into science.

Senator MALONE. We have had a theory here for some time called progressive education where the student picks his own studies and establishes his own future. What do you think of that method; what is the cause of this business?

Mr. EWELL. Well, there are a number of reasons why students aren't going into science so much. Probably the most important single one is the shortage of high-school science teachers. A very large proportion of high schools in the country, maybe even as many as half, don't

teach either chemistry or physics, which are the toughest fields to get teachers in, because chemists and physicists, even if they are not first-class scientists, can go into industry and make three or four thousand dollars a year more than they make as high-school teachers. There has been a very large flow of high-school chemistry teachers going into the industry.

Senator MALONE. What does that do when the high school has no science teacher; does it mean they go into college with a deficiency there that makes them dodge this course? They might think it is a little tough for them.

Mr. EWELL. They haven't developed any interest in science. If they go to college at all, they will study history or literature. As a matter of fact, the biggest increase in college enrollment in the past years has been in business administration. Business administration is the only field which has been increasing during the past 4 years. Everything else has been decreasing.

Senator MALONE. Why, do you think?

Mr. EWELL. I haven't heard any explanation of it.

Senator MALONE. It is not a very difficult course, I guess.

Mr. EWELL. I guess they just feel they want to get into business. Of course, there has been a sharp drop in enrollment in college since the peak, which I think was 1950 to 1951, during the GI wave. All college enrollments have been dropping sharply, but science and engineering have dropped even more sharply than the average.

Senator MALONE. What would cause the reverse of the trend, in your opinion?

Mr. EWELL. Well, an increase in the number and quality of high-school science teachers, I think is probably the most fundamental single thing.

Senator MALONE. Do you think it has entirely changed in the last two decades? It seems to me I remember I went to the university in 1913 because I thought I had to have the training to do what I wanted to do. Do we have any ideas of that kind any more?

Mr. EWELL. Well, a high-school student who wants to study science or engineering in college has got to have some motivation, either from his family or some friend or very frequently from a high-school teacher.

Senator MALONE. Maybe he could see somebody in the business that he wanted to be like and drawing a salary that he would like to get.

Mr. EWELL. Well, a great many of our high-school students just don't have that opportunity. You might have a brilliant boy in Little Rock High School and he doesn't know anybody in the scientific business, and he decides not to go to college, even though he is quite brilliant. As a matter of fact, in the high I. Q. group in the high school graduates in the country, 120 and higher I. Q., only 30 percent graduate from college. In other words, we are losing about 70 percent of our potentially intelligent people.

Senator MALONE. Maybe it is too easy to make a living without any of this training.

Mr. EWELL. Well, I don't know. It is a matter, of course, of high-school teacher motivation, family attitude, community attitude, and finances are certainly a stumbling block in many cases. Now, the National Science Foundation is supporting a study in the State of

Minnesota to contact high-school graduates in that State who had I. Q.'s of over 120 and didn't go to college, to find out why they didn't go to college, what line of work they went into, how successful they were, and what were their contributions to their communities.

Senator MALONE. Has there ever been a followthrough on these I. Q.'s to see where they go in comparison to just the plodders?

Mr. EWELL. Very few.

Senator MALONE. Do you know the ones that do go to college or the ones that don't?

Mr. EWELL. Well, when you start studying their I. Q.——

Senator MALONE (interposing). What is an I. Q.? Explain it.

Mr. EWELL. Well, it is called the intelligence quotient. I am not a psychologist, but it is supposed to be a measure of native intelligence, and it is generally accepted among the manpower people that 120 I. Q. is the lowest I. Q. at which you can expect to develop a reasonably good scientist, or a reasonably good lawyer or doctor or business executive.

Senator MALONE. What is a high I. Q., and what is a low I. Q.?

Mr. EWELL. Well, a hundred is the average; the mean of all people in any age group is 100 by definition; 120 is the average of college graduates.

Senator MALONE. What do the highest run, that is, the highest 25 percent, say?

Mr. EWELL. Well, I think about 120 plus, that is, 25 percent have 120 or higher. Genius is around 160 or 170, just to give you a figure there. There are a good many studies of what high I. Q. college students have done in later years. There was a very famous study made at Stanford University.

Senator MALONE. What was the result?

Mr. EWELL. I don't know. I have known some in that so-called Stanford group that were great successes and others that weren't.

Senator MALONE. Well, what do you call a great success, to become a Government adviser some place, head of a bureau?

Mr. EWELL. Well, successful business executives. A number of top executives at Standard Oil Co. of California and Shell Oil Co. were among this Stanford gifted-children group.

Senator MALONE. Well, it is very interesting. I have always sort of thought that if there is an incentive a boy takes care of himself, if he can just see that he can get any place.

Mr. EWELL. Well, the most aggressive ones, yes, but there are still many gifted people who could make great contributions in the form of science and engineering who are sometimes not aggressive and without motivation.

Senator MALONE. What do you have to have, some kind of a truant officer pick them up and head them through college?

Mr. EWELL. Well, it is a broader problem than I could cover here, but it is an obvious waste of some sort. It may become, in fact I believe it will become, a national problem; if the Russians are able to get a larger proportion of their high-intelligence kids into productive sectors of the economy, into engineering and medicine, we have got to do likewise or we will be left behind.

Senator MALONE. Well, some of the things that we are doing don't require a high degree of intelligence; just a little horsesense would be of more benefit than anything else back there in Washington.

Mr. EWELL. Maybe real horsesense and high intelligence are the same thing.

Senator MALONE. I am not so sure. There is more education in Washington, D. C., and less common horsesense than any place I have ever been.

Mr. EWELL. I would like to point out to you, Senator Malone, I have only been a Government official for 1 year. My prior experience has been in industry and research.

Senator MALONE. There is no reflection.

Mr. ADLERMAN. I don't think there is any connection between intelligence quotient and education.

Senator MALONE. Some of the most intelligent people in Washington, operating in the last two decades, have brought us right up to the brink.

Mr. EWELL. Yes. There are intelligent people that certainly have peculiar slants sometimes.

Senator MALONE. They were so smart they could write a piece of legislation with a double meaning and about a decade later Congress would recognize what they passed.

Mr. EWELL. I thought you would be interested in this scientific manpower situation, Senator Malone. Representative Hinshaw and Senator Saltonstall and certain others are familiar with it.

Senator MALONE. Yes. We will return your testimony to you, and if you care to edit for completeness and accuracy and give us a good picture of what your research shows, it would be appreciated.

Mr. EWELL. Fine, and thank you very much.

Senator MALONE. Mr. Robert Miller, Stanford University Research Institute.

STATEMENT OF ROBERT C. MILLER, STANFORD RESEARCH INSTITUTE, PALO ALTO, CALIF.

Senator MALONE. In line with Mr. Ewell's testimony, I think it was very interesting to the subcommittee, but I think the mining industry is a case in point. The profit has been taken out of it, and there is no incentive for anyone to study engineering that the chairman can see because there is no future in the mining business. Most mining engineers have devoted 5 or 6 years to college and postgraduate work, and then they have 15 or 20 years' experience before they feel qualified as consulting engineers. The end result doesn't justify it because there is no profit in the business. They have to then go back to the Government and get money to go into mining.

Mr. Miller, I am very much interested in the title of your subject, General Research, Strategic Materials, Beneficiation Processes. As you probably heard the chairman say, there is just sometimes only a very little difference between country rock and ore, maybe a little better method, cheaper method of beneficiation. My daughter attended Stanford University in the late thirties. It is a good institution. We welcome you here and whatever information you have that you think will be of value to the subcommittee, will you just present in your own way, submit it for the record.

Mr. MILLER. All right, Senator. We have brought along four exhibits here of the activities of Stanford Research Institute. One of them is on zinc recovery.

And this chart shows the beneficiation of Ione sands. The two publications of Stanford Research Institute here are the Western Resources Handbook and the Chemical Economics Handbook.

Senator MALONE. Let me see one of—the Resources Handbook.

GROWTH AND WORK OF STANFORD RESEARCH INSTITUTE

Mr. MILLER. Stanford Research Institute, as a public-service, nonprofit organization serving primarily the 11 Western States, has made contributions in several areas to the subject of critical materials and the needs of our Nation in times of emergency. These research contributions range from economic studies designed to reveal the change of availability of a critical material with time and changing circumstances to the development of new materials with superior properties thereby allowing the replacement of a critical material employed in essential uses. The magnitude of these research efforts may be visualized from a recent summary which revealed that 48 projects involving minerals, materials, and fuels have been undertaken by Stanford Research Institute in this area during the past 7 years with an average budget of $20,000 per project. A partial list of these projects is attached. Present research efforts are substantially above the level of effort given by these figures. During the early portion of the 7-year period, the institute was a small and growing organization with less than 100 employees. The present staff of over 800 employees is a rough measure of the expansion in research activity. The institute has completed more than 1,000 projects for more than 500 companies.

Many of the research projects of the institute are undertaken for private individuals and companies. These supporters of projects frequently request that the results, and even subjects, of research be kept confidential. The following brief discussion of the institute's activities in the field of critical materials must be read with that restriction in mind.

The general area of economic studies has grown to be one of the largest at the institute and an important contributor to our knowledge of critical materials. A general contribution in this area is the Western Resources Handbook, a compilation of data on all of the resources available in the 11 Western States, including the production and reserves of minerals, processing facilities, and other data to assist in drawing economic conclusions. These data are presented as graphs and tables to facilitate the visualization of our declining reserves and expanding consumption of many critical materials. The Western Resources Handbook, one of the public-service activities of the institute, has proved an invaluable aid to studies of the problems of the West and its mineral resources.

Another publication of Stanford Research Institute offered as a public service on a subscription basis is the Chemical Economics Handbook, a looseleaf set of volumes presenting important aspects of chemical economics. This handbook includes graphic and tabular data on production, sales, imports, exports, prices, and end uses of chemicals and related products including metals, minerals, and fuels. Significant trends in raw materials and substitution of products are indicated by the data.

An example of an economic project relating to strategic materials in the West was a study of petroleum reserves and a projection of those

reserves to several dates in the future. Such a study helps to emphasize that an eye to the future is important to private industry as well as to our National Government. Similar studies have been made for timber, natural gas, and other individual items such as zinc ores. A conclusion common to all such studies is that new processes to handle lower grade materials and better methods of prospecting are continually needed and demand research if success is to be achieved.

Of narrower scope but related directly to strategic materials have been numerous studies of the market for western minerals and their derived products. Such studies frequently lead to the decision to install new production facilities and, hence, to a greater supply of a strategic item. Studies of this type have been made on special clays, refractories, zinc, copper, and vanadium.

Research on reserves of critical materials has not been confined to economic studies but has included the development of new exploration techniques applicable to subsurface structures. Of outstanding importance has been the development and application of a new and improved seismic technique which uses charges suspended in the air to generate a shock wave whose reflections help to reveal the nature of the underlying strata. The method has been found applicable to the measurement of thickness of glaciers, explorations for oil, and the mapping of geological structures of iron-bearing ores.

A second exploration technique helps to reveal the nature of underground strata by means of a chemical reaction using a probe suspended within a well and in contact with the strata themselves. This technique helps to resolve many of the uncertainties left after other comparable techniques, such as radioactive well logging, have been used. The chemical nature of deep lying strata will in many cases be revealed by this new technique.

In addition to research on methods of locating minerals and other underground deposits, a number of metallurgical processes have been investigated in search of methods for handling ores not suitable to present commercial practice. An example of a research project in this field has been an alkaline electrolytic method of obtaining zinc from its oxidized ores which occur commonly in the West. By dissolving the zinc with alkali directly from its oxidized ores and electrolyzing the alkaline leach solution after purification, it is possible to handle such ores profitably when the price of zinc is above 12 to 14 cents per pound. This process has been successfully demonstrated with a pilot plant but has not been commercialized because of the fluctuating price of zinc during the last 5 years. Similar process metallurgy investigations have been made on vanadium and copper processes.

Other metallurgical studies have been made to develop procedures for handling specific ores when the established processes have been inapplicable because of interfering materials. In this connection a method was proven for handling an ore containing copper, nickel, and zinc with the recovery of products readily sold in the market.

Considerable research has been done to establish methods of beneficiating clays from the West so that the various fractions would readily find markets. Recently two plants were constructed to produce glass sand, ceramic clay, and paper clay from a deposit in California which was first examined by the institute to establish its commercial possibilities.

Another sphere of research at Stanford Research Institute relating to critical materials has been to establish the possible uses and markets of various mineral deposits. A thorough analysis of the nature of a natural mineral deposit, followed by careful laboratory studies of its possible uses, is necessary before a sound commercial enterprise can be established. Several studies of this general type have been carried out on clays, pumice, diatomaceous earth deposits, and a number of metalliferous deposits including zinc, lead, and zirconium. Stanford Research Institute's team of metallurgists, chemists, economists, and market analysts are fully qualified to undertake such wide-ranging studies. Industries founded upon conclusions rising from such thorough analyses are sure to have the best probability of survival. In one pertinent case history, a mineral occurring in the desert was studied and a method was developed for beneficiating the deposit. A study of uses and potential markets opened up a new use for the beneficiated product so that its value became several hundred dollars per ton instead of $30 to $40 per ton for the crude product. This enterprise is in a very sound financial position as the result of the research.

The improvement of processes in metallurgy, thereby allowing the handling of lower quality ores, is not the only answer to a dwindling supply of a critical material. In some cases the more logical approach is to develop a replacement, or preferably a superior, material by research. Ultimately the best solution is to replace a critical material since dwindling supplies will eventually force the adoption of a replacement when the rising cost of the critical material creates an unsound economic situation. Studies on corrosion and protective coatings fall within this general area since the economics of any item is markedly dependent upon the expected life of the item. The institute now possesses a unique instrument for such corrosion studies through its ion-scattering analyzer. This device is capable of determining the nature of corrosion products by analyzing for the elements present in the surface layers of a solid, using the scattering of protons as an analytical tool. This instrument should considerably enhance our knowledge of the nature of corrosion deposits and should therefore ultimately lead to improved methods for combating corrosion.

Of less general importance but more critical in relation to our present problem is the question of materials suitable for use at high temperatures. One troublesome area is those points in a rocket or jet engine where hot gases come into contact with structural materials. The requirement for good strength at high temperatures is further complicated by the necessity of extreme resistance to thermal shock and in many cases also resistance to oxidative attack. One approach to this problem has been to attempt to combine the high temperature resistance of metallic oxides with the good high temperature properties of a few high-melting metals and alloys. These physical mixtures, called cermets, are promising in some respects, but have not been completely successful.

The institute is attacking the problem by utilizing the excellent high temperature properties of graphite and learning how to protect the graphite from oxidative attack at temperatures up to 2000° C. Results appear promising and it is anticipated that the combination of low weight, good thermal shock resistance, and good high temper-

ature strength will serve to find a place for special graphite compositions in this troublesome area for critical materials.

In summary, the problem of critical materials can be alleviated in whole or part by research leading to better prospecting methods, improved metallurgical processes, new and improved materials, and better economic planning for the future. Stanford Research Institute hopes to continue its contribution in these general areas.

That is the end of the statement.

Senator MALONE. I am very much interested in your research. I addressed your university professors down there, it seems to me like about 1940. Do you have in your library an Industrial Encyclopedia of the Eleven Western States?

Mr. MILLER. Yes, sir, we have. It was one of the sparks which started this Western Resources Handbook on its way.

Senator MALONE. That is what I thought. You are looking at a man there that prepared the nonmetallic section on the Industrial West Foundations. I am very interested in these maps, because they are kept up to date. They are very valuable for reference. It was the intention of the Industrial West Foundation directors to keep their industrial surveys up, much as you are running this, but it was published in 1944, during the war, and I was the director of it, and I was also then, or had become the special consultant to the Military Affairs Committee on Strategic Minerals and Materials, and the Secretary of War, and also on examination of military establishments, the report on Dutch Harbor, and the report on the South Seas under MacArthur. Then I got so mad I ran for the Senate, and that sort of left the Industrial Foundation high and dry for a while, and then I heard that you had taken it up there and carried it on. It is a very interesting compilation.

How many of these volumes do you have that you keep up to date?

Mr. MILLER. There are three in the set now. It is possible that an additional volume will be added next year. These others are a total of five volumes now and they are the Chemical Economics Handbook. Dr. Ewell, who is on leave of absence from the institute now with the National Science Foundation, was instrumental in starting that.

Senator MALONE. It is more of a technical chemical book then?

Mr. MILLER. It deals mostly with chemicals. However, it deals also with a number of metals and other materials.

Senator MALONE. I remember that we debated in our board of directors whether we would publish it first in looseleaf form, such as you have published, or a bound volume, and we decided on a bound volume because it was during the war and there was no opportunity to carry it on, as long as the personnel only consisted of one man who had contracted other work.

How do you run it, what is the charge for the service, how do you support it?

Mr. MILLER. The Western Resources Handbook and the Chemical Economics Handbook alike were launched by institute funds.

Senator MALONE. Now, where did they come from?

Mr. MILLER. The institute was formed in 1946 by a group of west coast industrialists who saw the need for an applied research center in the West.

Senator MALONE. What do you call the institute?

Mr. MILLER. Stanford Research Institute.

Senator MALONE. And who were the industrialists?

Mr. MILLER. They were a group headed by Mr. Athol McBean. Do you know Mr. McBean?

Senator MALONE. I think so.

Mr. MILLER. He is a prominent west coast industrialist and the founder of Gladding-McBean Co., a ceramics firm.

Senator MALONE. What other firms were in it at the beginning?

Mr. MILLER. W. L. Stuart of Union Oil Co.; Paul Davies of Food Machinery Corp.; Win Fallis, chairman of the board of Standard Oil Co.; George Parkhurst of Oronite Chemical Co., subsidiary of Standard Oil Chemical Co.; and of course there were members also from Stanford University. Stanford Research Institute is independent of Stanford University.

Senator MALONE The institute was formed by——

Mr. MILLER (interposing). These companies in cooperation with Stanford University, yes. We are part of the family, but we are not part of the university.

Senator MALONE. What was the amount of funds contributed?

Mr. MILLER. Stanford University alone put up $500,000 and later an additional $125,000, and then the banks loaned an additional $600,000. All of that has been paid back except $560,000 of the loan from Stanford University.

Senator MALONE. What kind of a service do you render and how do you conduct it?

Mr. MILLER. We offer service in three general areas of research; economic research, engineering research, and physical sciences.

Senator MALONE. And then you charge for this service?

Mr. MILLER. Our work is done on a project basis. We are a nonprofit organization.

Senator MALONE. Who pays your salaries?

Mr. MILLER. We charge for our services on the basis of actual costs of salaries and equipment and materials that go into projects.

Senator MALONE. What is the extent of the personnel that you employ?

Mr. MILLER. As stated, we have over 800 people now in our organization.

Senator MALONE. Steadily employed?

Mr. MILLER. Yes.

Senator MALONE. They are made up of scientists and engineers?

Mr. MILLER. Economists, mathematicians, psychologists, practically the whole gamut.

Senator MALONE. All on the grounds of Stanford?

Mr. MILLER. The main body of the institute is located in what was formally Dibble Hospital in Menlo Park, adjacent to Palo Alto. The economic research division is in Palo Alto, on University Avenue. The institute has smaller laboratories at Mount Lee in Hollywood and in Pasadena. Field offices are located in Los Angeles; Portland, Oreg.; Phoenix, Ariz.; and Washington, D. C.

Senator MALONE (looking at the Western Handbook). Well, it seems like it was a pretty good idea I had. I would like very much if the subcommittee might have a set of your three volumes.

Mr. MILLER. I think we have perhaps submitted for the benefit of the subcommittee most of the information.

Senator MALONE. Now, you have heard the hearings this morning, you have no doubt reviewed the report. We are only started. We are looking now for any research, or information, that would lead to a proper conclusion as to what principle should be laid down by Congress to stabilize our economy, strengthen our economy in general production and for our security.

Now, Oliver, our ace in the hole always, you heard the testimony for 2 days, you know about Resolution No. 271 that continued the work of the subcommittee, you are entirely familiar with all the work the subcommittee has done, you have helped in most of it, been responsible for a lot of it, and you, over the last 20 years, have generated a good many ideas that have gone into it, so I would appreciate it if you would just take a few minutes and give us some advice as to what direction you think the work of the subcommittee can be most helpful to the Senate and the Congress and the fields that you feel we ought to deal with. I think you realize the seriousness with which we are approaching this work and maybe you are one of the few that does realize it. It makes me as chairman of the subcommittee feel very humble because of the tremendous amount of work and energy that is necessary and that has gone into the research into the fields that we are trying to go into in a very short time to get a résumé in shape so it can be understood, and arrive at some proper approaches to the problems.

STATEMENT OF OLIVER RALSTON, CHIEF METALLURGIST, BUREAU OF MINES, WASHINGTON, D. C.

Mr. RALSTON. My name is Oliver Ralston, Chief Metallurgist, Bureau of Mines, Washington, D. C. Well, Senator, I have listened to a great deal of the testimony and I have read much that I did not have a chance to hear. It seems to me that you have assembled a tremendously useful volume of facts about the mineral industries from all angles, and I think your enterprise is gathering impetus rapidly. You have been preaching in the subcommittee hearings and outside, the gospel as you see it, and I think it is bearing fruit. The hearings previously have not dealt too much with substitutes, replacements, and conservation of mineral products. The Dow Chemical testimony this morning really was a project in conservation of metals. We have been told in qualitative terms for a long time how much of our iron and steel produced each year goes back to rust each year.

Senator MALONE. It was a surprise to me, a shock.

Mr. RALSTON. Well, he had more quantitative figures. When you have quantitative figures to get your thumb on, then you can begin to talk about something that needs to be done.

I have appreciated a great deal the opportunity to listen to testimony here. I gather from the way you have called me that this is the end of the hearing.

Senator MALONE. Yes; we are closing with you for San Francisco, then we open in Washington sometime later.

Mr. RALSTON. I had that in mind, too. Well, I look forward to continuing to help you, and I rather think that your South American trip is also going to be very useful.

Senator MALONE. I have made an official request for your presence on that trip. Have you heard anything about it?

Mr. RALSTON. Yes; it is approved.

Senator MALONE. I am glad to hear it.

Mr. RALSTON. So I feel I am very fortunate in being able to accompany you there.

Senator MALONE. We are fortunate to have you.

Mr. RALSTON. Some of the testimony there has been somewhat off the beam, people with special projects of their own wish to make them known to you.

Senator MALONE. I think that is unavoidable at times.

Mr. RALSTON. Yes, but on the whole we have had a very good set of testimony. The last two people have come in with very good things; the National Science Foundation is a new organization of the Government. We have had a statement of what their relations can be to this work, and they have money to put out for aiding research. The Stanford Research Institute has been one of the most phenomenal growths in research institutes since the end of the Second World War.

Senator MALONE. I was very happy to have had a hand in organizing the Stanford Institute. You never know where an idea is going to land, do you?

Mr. RALSTON. Well, I am very happy to have had one finger in it.

Senator MALONE. You had a real one.

Mr. RALSTON. In the same organization.

Senator MALONE. You remember the advice and counsel we had from many engineers and scientists, Dr. Cottrell, and our Stanford man, Dorsey A. Lyon, was the former head of the Bureau of Mines, was he not?

Mr. RALSTON. Cottrell was a former Director, and Dorsey Lyon was an Assistant Director when he left us.

Senator MALONE. Yes; and then both went on to greater accomplishments.

Mr. RALSTON. Yes.

Senator MALONE. Well, can you tell us any particular fields in this field of substitutes, replacements, and synthetic materials that you feel we particularly ought to follow through on?

Mr. RALSTON. Well, in times of stress when people can't get a definite commodity, they look into substitutes, and there has been a tremendous amount of work done in the past 12 years. There is a large record scattered through all of the technical literature, of efforts in replacements, substitution, or economical use and conservation; to try to assemble all of it would be a monumental task, particularly if you were trying to assemble it in the form of testimony, because it would fill many books written in formal style, codifying this information. It would take quite a staff to assemble it because of a great deal of what was done was done by individuals. Some of them never made public what they did, but I think they would all be glad to chip in their experiences.

Senator MALONE. Of course, we realize that you have to be selective in this field, probably after our South American trip, we can select out of the 77 critical materials the ones that show the greatest problems. Now, that is something where I think you, working with our staff, could be very helpful. Your acquaintance is wide among the industrialists in the business, and I think if not before, certainly immediately following our return from this trip, it will be necessary to

determine what the field is going to be that we attempt to cover. Otherwise we might do a little too much shotgun work. We are going to get a compilation from this National Science Foundation. That might be a good start.

What do you think of that, Ralston?

Mr. RALSTON. I think it is very good. It takes a well-organized group such as we have been requiring and will be acquiring in the National Science Foundation. Stanford is also tooled up to such a project. Then, on the question of substitutes, you can't easily learn all of the things that have been done. It is still going to be a shotgun problem. You hit quite a few of the birds.

Senator MALONE. Well, at least we know what our objective is, and that is to funnel into our fund of information the basic facts and accomplishments in the work that is underway and then digest it as we try to do, put 10 volumes into 1 volume, consisting of recommendations then, again, and findings, perhaps, that are understandable to the Senators and Congressmen and make it available to them. Now, we have furnished a copy of this report, of course, to every Congressman and every Senator. So I feel that the subcommittee, as time goes on, pays its way in a compilation and a digest of the material which, as you say, is monumental. Now, if we can arrive at recommendations which should be followed by the Senate, that we think should be followed by the Senate, they can then take whatever action they see fit; but at least we have compiled for them the basic information which affects some of the major problems they have to vote upon.

Mr. RALSTON. Well, there have been many confidential things, reports, made to the military. Let's take as an example the Nike guided missile. We made certain components, alloyed steels and so on. The Department of Defense has also listed, in case the materials for a certain highly alloyed metal are not available, what is the next most acceptable alloy to use, and below that the next one, all laid out, in some cases as many as 10 or a dozen steps of replacements or substitutions. Now, that is strategic information because our enemies also would like to know just how they, too, can step down from one thing that becomes unavailable to something else that is still available. That information, of course, must be left where it is, in the right hands. You may want to know that it actually has been done; you may also want to talk with the military who have them, to learn how much more of each scarce material they would use if they could get enough, what weapons that are now being made in a satisfactory form would be vastly more satisfactory if we just had more of "X," more of "Y." There are plenty of beautiful plans on the shelf for lack of materials, plans for better weapons, better means of defense.

Senator MALONE. We still come back to one thing that I think is of value; you and I discussed it nearly 20 years ago, and that is what principle adopted by the Congress of the United States as the law of the land will induce people to invest their money and time in those industries which make the Western Hemisphere self-sufficient in the materials needed for the defense of our Nation, so that other countries cannot blackmail us because of a desperate need for critical materials and push us into war. A program which will contribute to these two objectives will constitute the field of work of the subcommittee. Do you agree with that statement?

Mr. RALSTON. Yes, most of the things that we normally consider are those that encourage peacetime economy, and your project is a matter of what policies must we follow in a war economy and to be always ready for a war economy, what policies during peacetime will promote stable economy and be ready for your emergency.

Senator MALONE. Does that complete your testimony?

Mr. RALSTON. Yes, that is it.

Senator MALONE. Well, Oliver, I appreciate very much your being here. I know, of course, that you will follow the mining organizations' work very closely. I hope that they do what they said they were going to do yesterday and pass some resolution that will be helpful to us. We appreciate your being here and deeply appreciate, the entire subcommittee, the work you have already done with us and for us and the cooperation of the Federal Bureau of Mines, which I again say, for the benefit of the record, has the best, has the most complete files on all of the mineral fields in which we are interested.

There have been several reports made where the material was used and quoted more or less accurately and then entirely erroneous conclusions reached, without any regard to the background of the material or the opinions of the men that furnished the material. I hope we have stopped at least temporarily that sort of a report.

Mr. RALSTON. Well, sir, the rain of statistics falls on both the just and the unjust and you can't prevent it. They will use that rain for their own purposes, which you have mentioned; mischievous use of statistics has been very important for a generation.

Senator MALONE. It has been just a little bit embarrassing to some of them, too, if they have lived to see it, and it may become more embarrassing for people that have an objective already set and then slant the data and the statistics to meet the objective, but that is our own fault, that is our own fault in the long run, so with that the subcommittee will stand in recess until the call of the Chair.

(Whereupon, at 6:10 p. m., the subcommittee adjourned, subject to the call of the Chair.)

STOCKPILE AND ACCESSIBILITY OF STRATEGIC AND CRITICAL MATERIALS TO THE UNITED STATES IN TIME OF WAR

MONDAY, OCTOBER 25, 1954

UNITED STATES SENATE,
MINERALS, MATERIALS, AND FUELS ECONOMICS SUBCOMMITTEE OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Reno, Nev.

The hearing was called to order at 3:53 p. m., Monday, October 25, 1954, in the Auditorium State Building, Reno, Nev., Senator George W. Malone, chairman of the subcommittee, presiding, and Tom Smith, administrative assistant to the chairman, and Jerome S. Alderman, counsel to the subcommittee, present.

Chairman MALONE. The subcommittee will be in order.

In 1953 the Senate of the United States passed Senate Resolution 143 creating a committee to investigate and report to the Senate the accessibility of critical materials in time of war for expanding economy and for our security. It developed that there were 77 minerals and materials, including agricultural products, properly classified as critical. The committee started hearings on the occasion of the American Mining Congress at Seattle, Wash., in late September 1953; completed their hearings in 1954; heard 360 witnesses at 58 hearings all the way from Seattle to Los Angeles; Henderson, Nev.; Salt Lake City, Utah; and Washington, D. C., and the Minerals, Materials, and Fuels Economic Subcommittee reported to the main Committee on Interior and Insular Affairs, and thence to the Senate; and on July 9 the report was submitted to the Senate and printed as Senate Report 1627. The report contained 12 recommendations, 14 findings, with an introduction and the remainder of the approximately 400 pages of the report constituted supporting data. In general the report demonstrated that the Western Hemisphere could become self-sufficient in the production of all of the critical materials, considering substitutes and replacements either for war or peace.

Also, it was necessary to determine what areas could be defended in the first go-around of world war III, if it comes. Generals Wedemeyer, Bonner Fellers, Carl A. Spaatz, Major de Seversky, an outstanding airman, and the testimony of Charles E. Wilson, Secretary of Defense, together with his Secretaries of Air, Navy, and Army, produced no information that weakened the testimony of the men already mentioned, that the Western Hemisphere could be defended. As a matter of fact, it was the only area that could be defended in the first go-around of world war III, if it comes, and then as we regain control of the air over areas across major oceans, such as Africa, Europe, and Asia, then transportation of materials and men could again

be made. But the sources of critical materials across a major ocean would immediately be unavailable to us in the event of an all-out war.

The evidence showed that 900,000 tons of manganese is being shipped from India to the United States annually, that that is about one-half of what we use annually, and that it would be immediately unavailable in case of war. It showed that our uranium ores are coming largely from the Belgian Congo and other sources across major oceans, and would be unavailable; tungsten coming from the original source, Burma, China, other nations; tin from the Malayan States, Indonesia—all would be unavailable immediately within hours after the war started.

This report showed:

1. The Western Hemisphere can be defended.

2. The Western Hemisphere can become self-sufficient in the production of critical materials necessary to live in peace or to conduct a war.

3. Defense of any area that we may elect to defend, including the nations of the Western Hemisphere, must be done with sonic-speed, long-range aircraft, submarines, and guided missiles, based in North America that can destroy the heartland of the enemy nation. It cannot be done with foot soldiers in the jungles, deserts, and mountains of Asia, Africa, and the Middle East.

4. Our own domestic economy can be improved and strengthened through Congress reasserting its constitutional responsibility of regulating foreign trade and adjusting the duties in accordance with article I, section 8 of the Constitution.

5. The spirit of the 130-year-old Monroe Doctrine should prevail in our relations with the nations of the Western Hemisphere and of the world—let it be called the enlarged Monroe or the Eisenhower Doctrine, include the areas important to our security, and be accompanied by simple pronouncement that any nation which seeks to enlarge its political, economic, or military power within that area will subject its warmaking potential to destruction.

Call it the American policy.

(Excerpt from report submitted for the record as follows:)

INTRODUCTION

AVAILABILITY OF CRITICAL MATERIALS IN TIME OF WAR

For the first time in the history of the United States Senate, a Senate subcommittee was directed to conduct an overall investigation of the accessibility of critical materials to the United States in time of war, particularly as to its effect on the security of the Nation.

The testimony before the committee is alarming: To a very dangerous extent, the vital security of this Nation is in serious jeopardy. We are dependent for many of our essential raw materials on sources in far-off lands, many under the control of possible fickle allies or timid neutrals, some veritably under the guns of our potential enemies.

And what is perhaps a more devastating conclusion of this committee is that none of this vulnerability need exist. Long overdue corrective measures should be undertaken at once.

The Minerals, Materials, and Fuels Economic Subcommittee of the Interior and Insular Affairs Committee derived its authorization by Senate Resolution 143 of July 28, 1953. It was directed to:

1. Determine the accessibility of the critical raw materials to the United States during a time of war.

2. Recommend methods of encouraging the production of the critical war materials adequate for the expanding economy and the security of the United States.

In pursuance of these directions, the subcommittee conducted hearings over the past 10 months from coast to coast and examined more than 360 witnesses. The most distinguished engineers, military authorities, scientists, and experts familiar with the problems of securing essential raw materials during wartime contributed their counsel and advice to the committee.

The subcommittee concentrated its examination on a total of 77 raw materials which the Secretary of Defense declares are indispensable and essential in conducting modern warfare and which we have acquired by imports from abroad.

The committee adopted at the outset three general areas of investigation vital to our national defense and to the maintenance of our national economy:

1. A study of the area from which critical materials will be available to the United States in time of war.

2. The degree of self-sufficiency that can be established within that area.

3. The congressional policy under which maximum economic self-sufficiency can be established in this Nation.

The investigation and report come at a very critical and uncertain period in the affairs of this Nation—when new and improved methods of offense and defense must be weighed and considered. Laboratory developments and discoveries, including substitutes and replacements for critical materials, all affect the long-range welfare of our people and our relations with the people of the Western Hemisphere and with the world.

The availability of critical materials essential to the defense of our country and which are vital to our civilian economy have strongly influenced our foreign policy. The known availability of the necessary critical materials in the Western Hemisphere, in an area that we can defend, should have a real impact on future foreign policy and defense decisions.

The Western Hemisphere can become completely self-sufficient in the production of the necessary critical materials in time of war. This Nation can materially increase its own economic production of strategic and critical materials by strengthening its laws regulating foreign trade. Congress cannot shirk its duties in this area.

The printed hearings, covered in this report, are divided into 10 parts as follows:

Part 1. Bureau of Mines
Part 2. Stockpile
Part 3. Titanium
Part 4. International Materials Conference
Part 5. Commodity trade agreements
Part 6. Fuels
Part 7. Tariffs and taxes
Part 8. Paley Commission, staff study
Part 9. Uranium, columbium, cobalt, rutile, and strategic agricultural products.
Part 10. Industry

COMMITTEE RECOMMENDATIONS

The availability of critical and strategic materials is vital to military security and to an expanding domestic economy. National survival in time of war depends on ample and uninterrupted supplies of the 77 such materials included in the report. To assure that imperative needs of the United States be met—

1. We recommend the closest cooperation among the nations of the Western Hemisphere, which is the only dependable source of the necessary critical materials in time of war. This area can be defended and can be made self-sufficient in the production of such materials. We recommend that the spirit of the 130-year-old Monroe Doctrine prevail in our relations with the nations of the Western Hemisphere.

2. We recommend that Congress insure that the regulation of foreign trade conforms to the principles thus laid down in article I, section 8, of the Constitution, thus assuring the American workers and investors equal access to American markets.

3. We recommend eliminating our Nation's present dependency upon remote and possibly unfriendly or neutral areas of the world for the critical materials, without which we cannot conduct a war.

The only tin smelter in the Western Hemisphere is in Texas City, Tex. The continued operation and maintenance of this smelter is essential to our security. The capacity meets our wartime needs.

4. We recommend increased depletion allowances to producers of critical minerals and materials as a further incentive to production [1]

Further studies should be made of the Canadian method of delayed taxation in connection with such critical mineral and material development.

5. We recommend acceleration of the Federal program of stockpiling critical and strategic minerals and materials to assure ready supplies in the event of war and coordination of this program with "going concern" production industries in the Western Hemisphere to assure continuation of necessary supplies under stress of war.

6. We recommend studies with a view to improve petroleum, gas, and coal resources and develop them to assure maximum availability of domestic fuels for both the peacetime economy and national security. Such studies should determine whether present regulations are unduly restrictive of our own resource expansion and reserves, and, if so, regulations should be adjusted to maintain our self-sufficiency in these vital fuels.

7. We recommend increasing the production goal for titanium to 150,000 tons annual minimum without delay. Titanium is a new wonder metal. This is a military must. Contracts should be awarded without delay by the Government to qualified concerns prepared to contribute toward this goal. Civilian demands are tremendous for this heat-resistant, high-strength-weight-ratio, noncorrosive, nonmagnetic metal.

This metal can become the basis for a 5 to 10 billion dollar new civilian industry. Production of the long-range supersonic speed bombers and the necessary fighter planes will make obsolete any nation's air equipment built without it.

8. We recommend that goals for production of uranium for fuel be made adequate to meet both military and civilian requirements. Hemisphere self-sufficiency in uranium for fuels can be attained. A liberal long-range market price must be maintained as long as Government control is necessary for security. A tremendous civilian potential use of uranium is assured based on nuclear power for industry.

9. We recommend a review of the work of the Securities and Exchange Commission by the appropriate committees of Congress to clarify its duties and responsibilities. The sale of securities affects the strategic materials program. It is recognized that the Commission should assure full and complete information to potential purchasers of securities, and that its responsibility does not include determination of feasibility. Such congressional committee review should consider the advisability of a requirement that a thorough and confidential inquiry should precede any public announcement of an investigation of offered securities.

10. We recommend determination by the Congress, through appropriate committees, of the precise duties and relationships between the multiple (approximately 38) agencies and branches of our Government responsible for stockpiling operations of critical materials.

The determination of these duties should precede the appropriation of funds for these agencies with the aim of facilitating their work and of fixing responsibility for the proper coordinated objectives.

11. We recommend appropriations of $50 million annually to establish and operate a comprehensive 5-year program of laboratory, pilot-plant, and exploratory research into improved methods of beneficiation of critical materials and the study of substitutes, including synthetics and replacements.

We approve the research and studies conducted by the Bureau of Mines on the low-temperature carbonization of coal and we recommend that adequate funds be appropriated to conduct extensive studies and investigations of ways and means to revive the coal industry. These funds should be made available to be used independently or in conjunction with responsible privately operated companies and organizations.

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[1] Present percentage of depletion allowance:

Mineral:	*Percentage of gross income*
Oil and gas properties	27½
Sulfur	23
Metal mines—practically all types	15
Uranium	15
Coal	10
Sand, gravel, slate	5

It is recommended that research and pilot-plant work be continued. That the erection of a large-scale oil-shale plant be considered by industry in cooperation with the Government. Such plant would endeavor to advance the production of petroleum fuel on a commercial basis, and it would be available in a war emergency.

12. We recommend rejection of international controls of production, prices, and supplies of critical and strategic materials unless by legislative action by the Congress of the United States.

FINDINGS

The findings include conclusions developed from the 10 parts of published testimony and are the foundation for the 14 recommendations for the United States Senate. This is in conformance with Senate Resolution 143 directing the committee to determine the accesibility of the critical materials to this Nation in wartime, and for our expanding economy and security.

1. The Western Hemisphere can be defended and will be the only dependable source to the United States of critical raw materials in the event of an all-out war.

The delivery of any such critical materials to the Nation across a major ocean during such a conflict will be highly problematical.

The evidence indicates that it now is possible for the enemy to destroy the production of critical materials at their source and, in any case, sealanes will be even more difficult and costly to depend upon than was the case during prior wars.

The Western Hemisphere can be made self-sufficient in the production of critical materials which are essential in war.

Since the testimony of competent witneses indicates that the Western Hemisphere will be the only dependable source of critical raw materials in the event of an all-out world war, it is imperative to the security of this Nation and to the nations of the Western Hemisphere that we and they foster the greatest measure of self-sufficiency in the production of such materials and continually study all possible devices that will encourage the expansion of hemispheric production in this vital field.

It is vital to our domestic welfare economy and security that maximum economic production be maintained, first, within our own borders and, second, in the Western Hemisphere.

2. During the last more than a quarter of a century established procurement practices have dangerously increased our dependence for the critical materials upon nations across major oceans without which this Nation cannot survive.

We must avoid dependence upon overseas suppliers to the extent that these suppliers could suddenly render us impotent by withdrawing supplies of critical materials during a world conflict, or could use such dependence as a political or economic bargaining lever.

Testimony is abundant that our domestic and foreign policies have been based on the false assumption that the United States is a have-not nation insofar as the supply of critical raw materials necesary to this Nation in wartime is concerned.

This testimony also shows that in many instances the United States has expended enormous sums of money to underwrite foreign fiscal systems and world policies of nations whose friendship is deemed of great importance because of their control and possesion of raw materials.

This misconception that we are a have-not nation has found wide acceptance by the public through confusion between the statistical and engineering terms, "proved commercial reserves" and "potential and latent resources," which include developed ore, probable ore, possible or inferred ore to designate supplies of ore in various states of development.

This confusion has led to predictions over the past two decades that we would soon exhaust our supplies of petroleum, iron ore, copper, lead, zinc, tungsten, mercury, and other critical materials. Expert testimony before this subcommittee made it crystal clear that there were more known commercial reserves of critical materials in the United States than ever before in the history of this Nation.

In the meantime we have consumed more than the total quantity of proven commercial reserves of two decades ago.

The potential latent resources or reserves are more than ever susceptible to discovery today by modern techniques and exploration methods, requiring only a financial incentive to be found.

Evidence was presented which showed that this country was led into the mistaken conclusion that, according to the known reserves of critical materials, including petroleum, tungsten, manganese, zinc, lead, and other minerals, "we would exhaust our supplies and they would be virtually depleted" within 2 to 12 years.

Documents were introduced into evidence which stated that in 1944 the Government was advised to conserve its minerals and that it should purchase some critical materials from foreign countries, including Russia. It was testified that this advice played a part in the subsequent increase in United States dependence on foreign nations for critical materials which are available in this Nation and in the other areas of the Western Hemisphere.

3. Less than 1 percent of the areas of this Nation has been included in geological investigations; only 12.7 percent has been geologically mapped, and 31.1 percent topographically mapped by the United States Geological Survey; and that the Survey started its mapping work in 1880.

4. The evidence indicates that Federal tax laws definitely retard the production of critical materials in this Nation.

The principle of depletion allowance has materially increased the known reserves of petroleum and natural gas and if extended to other critical materials would increase the incentive to discover and develop additional supplies.

5. The United States cannot possibly exhaust its present and potential fuels supply, including petroleum and coal, in the foreseeable future. The absolute necessity for going-concern industries cannot be overemphasized. This is particularly essential where materials cannot be stockpiled, as coal and petroleum. Testimony is conclusive that the petroleum industry is a thriving going-concern business growing through the effect of a continually increased market and the tax policies, including depletion allowances, but emergency dependence must be on the going-concern industry.

Enormous oil reserves are found in the shales and/or coal of Colorado, Wyoming, Utah, Kentucky, Indiana, and Ohio, as well as in Canada. It has been estimated these shales contain over 200 billion barrels of oil. Experimental work by the Union Oil Co. and Bureau of Mines in pilot plant operation shows that petroleum production from this source is entirely practicable and that vast amounts of oil may be produced in the foreseeable future. The Green River formation in Colorado alone has been described as an area of 1,000 square miles with an underlay of oil shale 500 feet thick averaging a recovery of 15 gallons of oil per ton.

Coal reserves are unlimited for energy demands as well as for petroleum production. The coal industry is in a state of decline and steps should be taken and studies should be made with a view to expanding the uses of coal.

An International Materials Conference was established in December 1950 by the State Department without the express consent of Congress. It was testified before the subcommittee that the IMC was set up in lieu of the International Trade Organization which Congress had refused to ratify at an earlier date.

There is evidence before the subcommittee that the operations of the IMC and international control of production and consumption allocations may have depleted and retarded fulfillment of stockpile objectives.

The IMC has now been discontinued. A new effort to establish a similar international organization is currently in progress in the United Nations Economic and Social Council, based on a resolution passed by that body on April 30, 1954.

An international organization, setting up controls over the distribution of the production and consumption of the world's goods could inhibit our own going-concern industries.

7. Ore is a mineral aggregate that can be extracted at a profit. Through properly regulated foreign trade the incentive for risk capital necessary to develop additional reserves and establish a going-concern critical-material industry will be available.

8. Mines once closed down require years of time and tremendous investments to reopen. With experienced workers and technical staffs widely scattered, machinery liquidated, mines flooded and caved, much of our once available reserves are destroyed, and prospecting for new reserves is discouraged. Failure to realize the situation could mean tragedy to our economy and our material security.

9. Numerous administrative agencies and departments of the Government are involved in the stockpile program, or in efforts to increase the production of critical materials. They act independently of each other and none are

charged with the complete operation. Many are not cognizant of the end objectives of the program. Their activities are marked by confusion and delay, frequently defeating the intent of Congress.

10. The Securities and Exchange Commission's "purpose is to provide full and fair disclosure of the character of securities sold" and "to prevent fraud." Complaints were made that the discovery and development of new minerals was retarded by actions of the Securities and Exchange Commission in that it improperly attempted to determine the feasibility of an enterprise and in that public announcements of investigations of securities sales were made prior to confidential inquiries justifying such announcements.

The Chairman of the Securities and Exchange Commission assured the committee that "the Commission does not pass upon the merits of any security or feasibility of an enterprise offering securities for public sale." The Commissioner also stated that there would be no publicity given to any administrative investigations before the Commission authorized a public hearing or announces a public investigation.

11. Titanium production is a must. It is a wonder metal without which this Nation cannot produce the most effective bomber plane flying at supersonic speeds with a range of five to seven thousand miles. Titanium will increase both the range and speed of these planes.

(*a*) This Nation needs a minimum production of 150,000 tons of titanium annually. The manufacture of the proper type of military planes without this wonder metal is impossible. We are producing approximately 2,000 tons annually.

(*b*) Three agencies share the responsibility for the production of this indispensable lighter, heat-resistant metal, which is far stronger than aluminum, and less than half the weight of steel. The Secretary of Defense, the Office of Defense Mobilization (ODM), and the General Services Administration (GSA) work on the program. The ODM represents the consolidation of about 15 such agencies.

(*c*) In 1953 the Secretary of Defense recommended the production of 35,000 tons of titanium annually by 1956. The ODM reduced the figure to 25,000 tons and up to September 21 of that year the GSA had let contracts for 13,200 tons and the actual annual production was little over 2,000 annual tons.

As of May 15, 1954, the Secretary of National Defense still recommends the production of only 35,000 tons, the ODM will permit contracts up to 37,500 tons. The GSA is now in process of negotiating additional contracts for an additional 16,500 tons per annum.

There is no provision for checking the contractees and for facilitating the work. Australia now furnishes the rutile for the Henderson, Nev., plant where two-thirds of the production is located—and India furnishes most of the ilmenite for the New Jersey plant, which is the source of the remaining one-third. Neither source would be available in time of war. There is more ilmenite in the United States and southern Canada than we can use in a century.

The industrial use of titanium, in addition to the military needs, could amount to from $5 to $10 billion annually in the near future—it is the strongest light metal known and in addition is noncorrosive, even in sea water. Many industries, including the chemical field, have announced that they can use the metal as fast as they can be assured a continuous supply.

12. The commercial use of nuclear power could be the greatest potential source of improvement, starting in the desert and mountainous areas where other fuels and hydroelectric potentials are high cost or nonexistent.

13. A stockpile of each critical material must be maintained which, coupled with going-concern production within the Western Hemisphere, will be ample to meet the military and civilian needs. Such a stockpile can be decreased as the going-concern production is increased.

The best wartime insurance of the adequacy of our supplies of critical and strategic materials is a healthy, expanding mining industry combined with well-balanced, ample stockpiles.

The availability of tin is a matter of deep concern to this Nation. The far eastern resources may well prove unavailable to the United States in any future war. The Western Hemisphere resources contained in Bolivia are more than adequate to meet the United States requirements. At present the United States Government is operating the only tin smelter in the Western Hemisphere. Recently efforts have been made to dismantle this smelter. Testimony received by the committee proves that this would be foolhardy and shortsighted. It is essential that we have a going-concern tin smelter in the United States capable of

supplying the United States in the future and to supplement our stockpile requirements.

14. Laboratory research, pilot-plant experimentation and exploration are important in the interest of national defense and must be implemented—for new and improved methods of beneficiating critical materials and for new uses, substitutes and replacements—and to facilitate the discovery of new reserves.

The difference in country rock and reserve ores often lies in an improved beneficiation process.

Numerous new uses for metals and materials have continually been developed over the years through laboratory work and pilot plants, among them titanium, zirconium, columbium, thorium, and uranium and new materials such as synthetic mica.

Many of these can be utilized as substitutes and replacements for scarce materials. They have opened up entirely new and unexplored fields of increased speed and power. There is every reason to conclude that if properly encouraged, much greater and broader progress in these fields lies immediately ahead.

List of Strategic and Critical Materials

Group I

Abrasive crude aluminum oxide, page 48 (page numbers refer to report)
Aluminum, page 48
Antimony, pages 43 and 190
Asbestos, amosite, page 47
Asbestos, chrysotile, page 47
Asbestos, crocidolite, page 47
Bauxite, metal grade, page 48
Bauxite, refractory grade, page 48
Beryl, page 52
Bismuth, page 53
Cadmium, page 57
Celestite, page 61
Chromite, chemical grade, pages 61 and 189
Chromite, metallurgical grade, pages 61 and 189
Chromite, refractory grade, pages 61 and 189
Cobalt, page 67
Columbite, pages 150 and 151
Copper, page 72
Corundum, page 78
Diamonds, industrial, page 78
Fluorspar, acid grade, pages 79 and 229 to 234
Fluorspar, metallurgical grade, pages 79 and 229 to 234
Graphite, amorphous lump, page 85
Graphite, crucible grade, page 85
Graphite, lubricant and packing grade, page 85
Kyanite, page 87
Lead, page 88
Magnesium, page 94
Manganese ore, battery grade, pages 95 and 188
Manganese ore, chemical grade, pages 95 and 188
Manganese ore, metallurgical grade, pages 95 and 188
Mercury, pages 100 and 186
Mica, muscovite block, good stained and better, page 105
Mica, muscovite block, stained (radio tube quality), page 105
Mica, muscovite film, page 105
Mica, muscovite splittings, page 105
Mica, phlogopite splittings, page 105
Molybdenum, page 107
Nickel, pages 107 and 150
Petroleum, pages 234 to 250
Platinum group metals, iridium, page 150
Platinum group metals, platinum, page 150
Quartz crystals, page 112
Rare earths, page 112
Selenium, pages 114 and 150
Tin, page 116
Titanium, pages 121, 195 to 197, and 199 to 212

Tungsten, pages 123 and 185
Vanadium, page 129
Zinc, page 130
Uranium, pages 214 to 219
Thorium, page 150

NONMINERALS

Bristles, hog, page 142
Castor oil, page 139
Coconut oil, page 139
Cordage fibers, abaca, page 138
Cordage fibers, sisal, page 138
Cotton, extra long staple, pages 141 and 145
Feathers and down, waterfowl, page 142
Hyoscine, page 137
Iodine, page 85
Jewel bearings, instrument jewel except vee jewels, pages 86 and 87
Jewel bearings, sapphire and ruby vee jewels, pages 86 and 87
Jewel bearings, watch and timing-device jewels, pages 86 and 87
Opium, page 137
Palm oil, page 140
Pyrethrum, page 137
Quinidine, page 138
Quinine, page 137
Rubber, crude natural, page 140
Sapphire and ruby, pages 86 and 87
Shellac, page 138
Silk, page 141
Talc, steatite, block, facing page 146
Sperm oil, page 140
Vegetable tannin extract, chestnut, facing page 146
Vegetable tannin extract, quebracho, facing page 146
Vegetable tannin extract, wattle, facing page 146

GROUP II

MINERALS

Bauxite, abrasive, page 48
Cryolite, natural, page 50
Graphite, crystalline fines, page 85
Ilmenite, page 198
Mica muscovite block, stained and lower, page 105
Mica, phlogopite block, page 105
Platinum group metals, osmium, facing page 150
Platinum group metals, palladium, facing page 150
Platinum group metals, rhodium, facing page 150
Platinum group metals, ruthenium, facing page 150
Rutile, page 197
Zirconium ore, Baddeleyite, page 136
Zirconium ore, zircon, page 136

NONMINERALS

Agar, pages 137 and 141
Cotton, page 141
Diamond dies, facing page 146
Emetine, page 137
Optical glass
Talc, steatite, ground, page 115
Wool, pages 141 and 192

Chairman MALONE. Now, Mr. Gordon, we have asked you to come before the committee because you are the secretary of the Nevada Mining Association. You are closely associated with other mining associations throughout the Western States and the Nation. You did appear before the committee early in its hearings, and you have had an opportunity to examine the work of the committee. The work of the committee is being continued under Senate Resolution 271. Senate

Resolution 143, of course, expires with the 83d Congress. This resolution is a little broader in its scope. It resolved that the Senate Committee on Interior and Insular Affairs, or any duly authorized subcommittee, is authorized and directed (1) to (continue) investigate and study the accessibility of critical raw materials to the United States in time of war for the expanding economy in time of peace; (2) to make a full and complete investigation and study of new developments and discovery of materials including synthetics which may be used as substitutes and replacements of critical materials, and further to study the progress of research programs, pilot-plant operations, processing and beneficiating methods of critical materials and minerals including fuels; (3) to make a full and complete investigation and study of the best means, methods, and devices to foster the greatest measure of self-sufficiency of critical materials that can be produced within the United States and the Western Hemisphere and to expand and develop the strategic materials industries; (4) to make a full and complete investigation, and study the status of the stockpile program, its goals, methods, and amounts of acquisition, storage, warehousing, and rotation programs; (5) to make a full and complete investigation and study the available fuel reserves of the United States and the Government regulations affecting such resources and to formulate and recommend a national fuel policy to assure maximum availability to meet the needs of the peacetime economy and for the national security in time of war; and (6) to report to the Senate its findings.

Now Mr. Gordon, you have had an opportunity to examine the work of the committee. It is planned and still is planned to take the committee to South America to determine the potential production in each of the South American countries; not that the committee could spend too much time in each place, but they could become familiar with the sources of such information, and with the leaders of the South American nations, and bring about closer cooperation, which is one of the 12 recommendations.

The committee is interested in information from you and from Mr. Roy Hardy, who happens to be one of the outstanding consulting engineers in the State and in the West, and familiar with production of critical materials, and also a regent of the University of Nevada.

Not only the importance of the work done by the committee up to date, but the field in your opinion that might be covered to advantage, be helpful to this Nation and to the citizens of the State of Nevada and the Nation in the future. If you will identify yourself for the purposes of the record; make any statement that you care to make that you think would be helpful to the committee.

TESTIMONY OF LOUIS D. GORDON, EXECUTIVE SECRETARY, NEVADA MINING ASSOCIATION

Mr. GORDON. My name is Louis D. Gordon. I am a mining engineer, and at present executive secretary of the Nevada Mining Association. As for the work to date by Senator Malone's committee, I think it has been a monumental work and of great benefit to the entire United States, if the safety of the United States is important, and it should be considered important by every citizen. I think the work of the committee should be continued, and I think that in time of peace or in

time of war the North and South American continents can furnish practically everything we need.

MINERALS INDUSTRY NEEDS PROTECTION

It should be remembered that we are short of tin, but that is available in South America. Nickel is available in Canada, and some of the metals and minerals of which a deficiency is alleged, given a proper price incentive with proper protection for American industry, a lot more of those metals or minerals could be produced. As far as Nevada is concerned the value of the production of gold, silver, copper, lead and zinc for the year 1953, according to the United States Bureau of Mines, is something over $42 million. Adding to that the value of the tungsten, manganese, iron, mercury, various nonmetallics such as magnesite, perlite, gypsum, diatomaceous earth, barite, and many other nonmetallics, the value of our production would be something over $70 million. We are second in production of manganese, we are first or second in production of tungsten, fourth in the production of copper. We are large producers of titanium. One of the largest titanium production plants in the United States is in Henderson in Clark County. We do need, however, some incentive in the way of tariff protection for some of the metals and minerals of which we are in need, or at least a guaranteed price; because it is impossible for the American mining industry to compete with the low production costs of Europe. The average pay of a miner in Nevada now is from $1.75 to $2 an hour, time and a half over 40 hours a week, and double time for Sunday. That is to say, an average of around $2 an hour for 5 days a week, then time and a half for Saturday and double time for Sunday.

I think the work of the committee should be continued. I have no sympathy with the dumping of cheap foreign metals on the American market because it will only result in closing down our American mines, and if we should be so unfortunate as to get into a war our foreign supplies will be cut off and we will find our American mines closed down. A mine can't be closed down and turned on like a water faucet. It sometimes takes months to rehabilitate a mine. Machinery deteriorates, the mine sometimes caves or fills with water. So there is no question in my mind about the value of the work the committee has done or the desirability of continuing the committee's work. It has furnished a vast fund of information, and I think that it has allayed a lot of misinformation which has been quite prevalent in this country with reference to our being a "have not" nation. We could become a "have not" nation as far as production is concerned if we favor foreign imports as against our own metal and mineral industry. That is to say, we could be "have not" in case of war for some considerable time. If we are not "have not" for the first part of the war, we could be "have not" for a long time thereafter.

I don't know of anything else, gentlemen, I can say or add to that. Any questions you'd like to ask?

Chairman MALONE. I was interested in your statement that there must be some principle laid down upon which private investments could be based.

Mr. GORDON. Unquestionably.

Chairman MALONE. Now, for two decades there has been an encouragement of imports from the low-cost labor areas, and people of the country have been told that they are entitled to this lower-cost material if they can get it; but the fact remains that our investigation shows that we do not profit economically from the imports, and in addition these imports make us dependent upon offshore areas in time of war, and therefore, this dependence on offshore areas could defeat us.

But a good example of this is mercury. It went to $250 or higher during World War II. Immediately following the war, being no tariff to amount to anything, or duty, as the Constitution of the United States calls it, on mercury, the mercury was imported from Spain and other sources for as low as $60 a flask simply because their wages were so very low. But, as soon as the American producer was out of business, and during World War II we were producing—we were just about current with the consumption, showing it can be produced here—the foreign price began to go up. Then it went up as high as $270.

Mr. GORDON. $325 now.

Chairman MALONE. $325 now. But it was $260 to $270 a flask just a few months ago. No mercury is being produced in this country, because the mines are shut down and there was no assurance that the price would stay up, so no money would be expended in opening the mines.

Now, as you have said, it is $325 a flask. If the domestic mines open tomorrow and we are seriously interfering with the foreign sales, the price would undoubtedly drop again, close the mines, and then go up again; so the only method, business method, would be to have a duty, as the Constitution calls it, in article I, section 8, that Congress, legislative branch, set the duties, imports, and excises. The authority was transferred to the executive department in the 1934 Trade Agreements Act, and the State Department has made these trade agreements—not properly trade agreements—agreements to lower tariff, so there is no protection to amount to anything; so the suggestion has been made many times that we allow that Trade Agreements Act to expire. It was passed for 3 years, first in 1934, then extended each 3-year period since to 1951, when some of us—I take most of the credit for that—cut it to 2 years' extension. Then, in 1953, it came up and was extended 1 year; extended again this year for 1 year. It now expires at midnight on June 12, 1955.

Many sensible people who have studied this thing through think it should expire, revert to the Tariff Commission, an agent of Congress, and the tariff on mercury and 5,000 other products be fixed on the basis of fair and reasonable competition with our chief competitive nation in each case. The duty or tariff would represent principally the difference in the wages and the taxes and the cost of doing business here and in the chief competitive nation on each product, and be a flexible situation such as is provided in the 1930 Tariff Act, with the Tariff Commission as an agent of Congress solely responsible for keeping that differential represented in the tariff. Then potential investors would view the situation and see that it would take a change in the law; they'd have to appear before Congress, have a bill and appear before congressional committees in order to change it, and probably would bring the money back into the investments not only

in mercury, but in all the other metals and the textiles and precision instruments and crockery and 5,000 other products.

Is that what you meant by a duty or tariff protection?

Mr. GORDON. That is exactly what I meant, Senator, and in addition, as far as mercury is concerned, we have been at the mercy, as I see it, of European cartels. Spain and Italy are the principal foreign producers of mercury. The history of the mercury industry has been that these cartels have depressed the price, closed down American mines, then raised the price and prevented closed-down American mines from taking advantage of it. Recently there has been a so-called floor put under mercury of $225 a flask by our Government until a certain number of flasks are purchased. I don't recall the exact amount, but I think it is 300,000 flasks, as I recall; 75,000 from Mexico, 225,000 from this country; but even that is $100 a flask less than the present market price.

I am an American first, and this whole thing appears to be that the United States is creating competition for itself. We furnished all these billions of dollars to European producers, which will never be repaid. The know-how, the modern machinery, all the possible technical advice. The average miner in Europe earns as much in a year as one of our miners does in a month. So our markets are flooded with the product of all this cheap labor without, as I see, any resulting benefit to the United States.

It might possibly benefit a few manufacturers on the eastern seaboard, but in time of war they wouldn't have anything to fabricate or manufacture as far as metals are concerned, because these overseas shipments would be shut off and we'd have our mines closed down; so unless there is some protection for the mining industry, some incentive to make a healthy mining industry in the United States, and to pay more attention to the North and South American Continents and forget some of these farflung overseas imports, we could get ourselves into a very bad jam. At least that is my considered opinion after years of study.

I think you brought that out very well in your report. We are self-sufficient if we have a decent price and some incentive and some measure of protection.

Chairman MALONE. What our people who seem to be deluding themselves that the American people were going to benefit from this protection mean when they say they can get it cheaper from foreign nations, they just find cheaper labor to produce it and use our machinery.

Mr. GORDON. We are paying for it, because we furnished them all this money with which to buy it. People forget about that.

Chairman MALONE. On page 370 of this report appears memoranda from Harry Dexter White, March 1944. We got an inkling of it through the testimony where he recommended to Morgenthau—he was assistant to Morgenthau, United States Secretary of the Treasury—that we secure our critical materials from foreign nations, loan Russia $10 billion to start them in production that they could furnish these materials to us; that we were out of these materials or the end was in sight, taking the known reserves of petroleum, manganese, tungsten, lead, zinc, chrome, mercury. On page 371 we have the table as he arranged it at that time. We'd be out of all those things all the way from 2 to 23 years. That would be the end of them.

Well, of course, he drew an entirely erroneous conclusion from what engineers call reserves.

Mr. GORDON. Well, he did that advisedly, didn't he?

Chairman MALONE. We think so. In other words, he was called a Communist, but he did sell this idea to Morgenthau. Morgenthau recommended it to the then President of the United States. That memorandum is printed here on page 372, and then the statement that the President made to the country based upon the Morgenthau statement also appears in the record here.

Mr. GORDON. You mean the Paley report?

Chairman MALONE. No, this was a release by Mr. Truman when he signed the stockpile bill, just saying that the policy of the administration was to buy foreign ores and save our own.

Now, that being the case, the country was pretty well flooded with propaganda, the Paley report one. Mr. Paley appeared before our committee. One of the things he said to the committee is that he didn't know anything about critical materials or minerals; also that he thought the recommendations he had then made would not have worked now. That I think is in the report.

Of course, there is another angle to all this in addition to national defense, which, of course, is very well set up, I think, and established that we could lose a war by the simple expedient of some nation powerful enough to close the avenues of transportation of these nations, but what does it do to our domestic economy? Minerals and agricultural products and textiles and crockery and all the rest of them to have the bulk of it shipped in? What is the effect on our national or domestic economy?

Mr. GORDON. Well, I wouldn't object to some critical materials, as a safety factor, being brought in and stockpiled and earmarked if our domestic economy wouldn't be affected, but that should be limited and strictly limited and shouldn't be based upon political expediency or the ideas of men of the type of Mr. White or Mr. Morgenthau or Mr. Owen Lattimore or Alger Hiss. There is some talk now of trading some surplus agricultural products for some critical materials abroad, but that should be very carefully considered and should be on a very limited basis, and if it is done it should be only for things in which we are definitely deficient, and those things should be positively earmarked and kept out of the channels of trade. I wouldn't want to go on record as to just how far that should go, but there is a possibility that upon study of a proper committee, and not on the basis of advice of men such as I have mentioned, a temporary program of that kind might not be out of line; but I wouldn't say just how far it should go or to what extent it should go, but it deserves some consideration.

But at the same time that should be done in a way not to in anywise affect our American production or our American industry.

Chairman MALONE. This committee intends to go further into that subject, but it has seemed to the committee so far that buying for a stockpile, you could very easily buy from our South American nations and encourage their production, and also buy from our own producers.

Mr. GORDON. I had in mind, Senator, South America and Mexico in that.

Chairman MALONE. In this hemisphere, that's what you had in mind?

Mr. GORDON. That's right.

Chairman MALONE. To that the committee fully agreed.

Mr. GORDON. I have no sympathy for trade with the Communist nations, or the Communist affiliated nations, if I may call them that, because some of our supposed friends are dealing openly and have been for years with Communist nations.

Chairman MALONE. They have never stopped dealing. It was established; as a matter of fact, I submitted 96 trade treaties in 1949 for the Congressional Record, the 17 Marshall Plan countries then had with Iron Curtain countries and Russia. Now they are openly making new agreements, of course, taking the money from this Nation to establish the factories to produce the products.

Mr. GORDON. So called neutral states fraternizing with Malenkov and Chou En-lai and all the other murderers.

Chairman MALONE. So if our military strategists are correct that we can defend this Nation, and it is the only one we can defend in the first go-around—then it behooves us it seems—and I understand from your testimony that is what you believe—to become self-sufficient in the Western Hemisphere, get out from under potential blackmail from foreign nations that may stop shipments, like India did, if we do not sign further agreements. Also then we welcome allies in a war, but you can fight your own fight if you have built your planes and are ready.

Mr. GORDON. I would say the North American Continent first and second the South American Continent, and I think with those two we could be self-sufficient.

Chairman MALONE. Well, that is what the committee said.

Well, now, this testimony of yours, Mr. Gordon, will be returned to you for correction and completeness. You may add any statement, anything that you think will be helpful to the committee, and if you could get it back by the 1st of December it would be very helpful.

Mr. GORDON. I will correct it as soon as I receive it; mail it to you.

Chairman MALONE. Yes.

Now we have Mr. Hardy, who is consulting engineer in private practice and a member of the board of regents, University of Nevada. Mr. Hardy, you have been before the committee before, and you are familiar with the committee work up to now. You know that that is under Senate Resolution 143. You know that the committee work has been extended under Senate Resolution 271. We do intend to take the committee to South America if this special session of the Senate does not interfere in the plan.

You are also familiar with the work that has been done at the university. As a matter of fact, you assisted in establishing a project there in our mining department to determine new and improved methods of beneficiating and in determining the effect of radiation dust on animal and plant life.

You are also familiar with the ideas that the chairman has had that we ought to have a reactor technology course established at the university, back of the Sierra Nevada Mountains. Most of the western technologists are located in Cal Tech, California University, Southern California University, where it is well known submarines could destroy not only the laboratory but probably the brains along with it in 24 hours.

Now, the chairman has discussed with you over the years, for maybe a couple of decades, methods that would increase, strengthen the economy of the State and the Nation and make us more secure in time of war, and that of course is the purpose of the Senate in passing Senate Resolution 143, and now Senate Resolution 271, and we want to keep in touch with the technical men and producers who assisted us in the beginning and get their ideas as to what they think should be done; so if you can proceed in your own way and give the committee the benefit of your advice and counsel as to what you think the value of the work so far has been, and what the committee should do in the future, it would be appreciated.

TESTIMONY OF ROY A. HARDY, CONSULTING MINING ENGINEER, RENO, NEV.

Mr. HARDY. My name is Roy A. Hardy, Reno, Nev. I am a consulting mining engineer, doing consulting work in different minerals, principally tungsten, uranium, gold and silver, arsenic. I wish to state, Mr. Chairman, that it has been a privilege to listen to Mr. Louis Gordon's testimony. I am fully in accord with everything he has said, and I have made a study of Senator Malone's subcommittee report on Strategic and Critical Materials, and as Mr. Gordon said it is a monumental piece of work. I believe the committee has done a great service to the country in showing the accessibility and availability of all these 75 or more strategic and critical materials to the United States and to its effect on the security of our Nation as well as for the expansion of our economy.

NEED FOR A NATIONAL MINERALS POLICY

A correct appraisal of our mineral resources should be made as your committee is doing, and by all means the work of this committee should be continued. Heretofore we have had several guesses put out in reports that have received considerable credence in certain quarters. Now they are purely guesses, and I refer to the Paley report and the Harry Dexter White reports, whereby bureaucrats—I say bureaucrats—the different bureaus accepted their findings as factual, and used their figures to a great extent, and by doing so they upset the economy of our country and caused untold distress in this western mining area in that they were the cause of closing down many of our producing mines, which as you know to reopen would cause untold expenditures and a great deal of time, and of course some of the mines are lost forever. It all spells to me that a healthy mining or minerals industry needs a national minerals policy, and we do not have that national minerals policy at this time. It is necessary to have such a policy to stabilize and make a healthy minerals industry, and this means: (1) stabilizing the monetary system which could be done by a gold standard. That is establishing a ratio of the dollar to gold. Allow our citizens to acquire gold and to have a free market as they do in other nations for their gold, which would necessitate stopping or curtailing the printing of untold paper money. (2) We need for stabilization a proper protection from the dumping of cheaply produced materials by foreign countries. We are accelerating that production by gifts of money and giving them the technical know-how

of production. This should stop and we should have a duty or a tariff to equalize the differences between our country and foreign countries as to wages and taxes, until the living standards of these countries are equal or the same as ours. And (3) a stabilization of the method we are now using to fix prices and fix amounts of materials to be purchased and placed in strategic stockpiles for the security and defense of our Nation.

But I believe this is more or less of an expedient and that we will have to have more protection. The country should make sure that the minerals industry continues as a going concern, and not allow a cessation of production of critical and strategic minerals, that they should keep the beneficiation plants in operation, especially those that are now in operation. Take, as an example, Nevada with our increasing production of minerals and metals, and for instance, the tungsten, domestic purchase program, which has probably less than 2 years to go before it expires; after which we will be faced by foreign dumping, and naturally most of our tungsten mines will have to cease operations.

So I would suggest to the Government, Congress, that they see to it that the beneficiation plants of strategic and critical minerals be kept in operation and that a suitable program of further stockpiling be entered into as soon as possible.

I would also suggest that manganese depots be established in Nevada as well as uranium ore buying plants and sampling plants. I further suggest that the committee investigate the feasibility of advising the Atomic Energy Commission to be a little bolder in building upgrading plants for uranium ores, so that the low-grade ores, the ores that have a value 0.05 and up will not be lost to our country.

Chairman MALONE. Is that because when test processing plants are not immediately available, or within the immediate area, that it is too expensive to ship the real low grade to where the plants now are?

Mr. HARDY. There are several, about 5 or 6, plants on the Colorado Plateau buying ores, but the miners find that they cannot make a profit unless they ship ores of a grade of 0.2 and up.

Chairman MALONE. Just costs too much to ship the ore?

Mr. HARDY. It costs too much. Those plants are too small. They could be used for upgrading of products from large plants that should handle lower grade materials. The small plants could finish the product.

Chairman MALONE. Is it your idea that if more of these plants were built and closer to the source of production of the lower grade material that then they could be processed without the excessive transportation cost on the low-grade material and perhaps it would pay?

Mr. HARDY. Your statement is correct. They should be placed in the locale of the mines that produce the ores.

Chairman MALONE. What is your general opinion, I am very much interested since you are perhaps one of the first private consulting engineers to get into this business of uranium, we believe—the committee concluded after hearing the evidence in Salt Lake City on the production of uranium, we made a particular study of it, that if any agreement was made to alleviate some of the tax burdens on producers of uranium ore that we'd become self-sufficient in the production of uranium ores in a surprisingly short time. Some of us estimated a couple of years, that probably in an emergency if we were shut off

from other sources could be self-sufficient. What is your general idea on that point?

Mr. HARDY. I believe that is true. I believe it is only true if we beneficiate the very low-grade ores. If we continue to select our ores we may not become self-sufficient. We could easily do it, become self-sufficient if we had the upgrading plants for the lower ores. We have an area out there, the Colorado Plateau area, with potential uranium-bearing ores covering between 300,000 and 400,000 square miles, and more recently we have had several important finds in Nevada, and I want to say that the Atomic Energy Commission people are doing a fine job of encouraging prospecting, but more work can be done to encourage the little fellow.

Chairman MALONE. Is this recent depletion allowance that we were able to get through the Senate Finance Committee and then through the Congress from 15 to 23 percent helpful?

Mr. HARDY. It is very helpful. In fact, it's stimulating to all the mining industry, the benefits from that increase in depletion.

Chairman MALONE. We included 31 minerals. Not all are produced in this area, but it was thought, at least I was able to convince the committee, that in some instances you might even get more revenue by having an increased depletion allowance, because you'd produce so much more of it that the actual money paid into the Government in taxes might even increase.

Mr. HARDY. That is true, and along that line I would like to suggest to the committee that they and the Government consider gold and silver as strategic and critical metals. They are absolutely essential to our way of life, and for the defense and protection of our country to have a sufficient stockpile of those precious metals, and I do not see why they cannot participate and have encouragement as a great injustice has been done to the gold and silver mining industry. They should be able to participate in the increased depletion allowances. That would partly alleviate some of the rank injustice that was done to the industry; but I wish to say further to the committee that with proper incentives of price structure the mineral area of this State, of the State of Nevada, has hardly been scratched, and that Nevada is capable of producing a great variety of minerals that are going to be so essential to this new era, especially the rare earths. And we are very grateful to the Bureau of Mines, the Department of Interior, for the fine building they have erected here for research into the beneficiation and the utilization of the rare-earth minerals and I understand they are going to start with cerium. The prospector, the little fellow, is beginning to get very scientific in his work, and I think the economy of this State is going to be greatly enhanced. The little fellow, as I say, now goes out with a fluoroscope and a spectrograph, a Geiger counter and probably a scintillator, where before he used to go out with a gold pan.

So it is bound to have its effect on the economy of our State. Nevada has a great storehouse of minerals, and we by no means are a have-not Nation. We just need the incentives to go out and get them, the minerals that are necessary for the defense of our country.

Chairman MALONE. A remark dropped by former President Herbert Hoover—and I know that you and I will agree as long as he lives that he is one of the greatest consulting engineers in the world—in one of

our conferences, and I have had many with him over the years, became a very good personal friend from the time he was head of the Department of Commerce before he was President. I visited him in New York City during the course of this investigation, wanted him to appear before the committee, but he thought he was doing some work for the President and probably shouldn't try to do too many things at one time. He did write a very comprehensive letter, as you know, which is included in the report, but I showed him the preliminary report on several minerals, including tungsten, as we were sitting down to breakfast, and he hardly looked at it. He just said in that quiet voice, "You and I know there is enough tungsten in Nevada to run this country 50 years," and I said, "Yes, Chief, you know and I know it, but the country has been sold that we do not have it, and do not have many of these materials. So the problem is to bring it before the people."

Now when you talk, first, in your remarks on gold and silver, as chairman of the committee I fully agree that the foundation was pulled right out from under our economic system when we went off the gold standard and started printing the money. In other words, it is worth now less than half it was before, so all the tariffs and duties and everything just as one item were lowered through inflation. If there was a 5-cent-a-pound duty, and the price per pound of the metal or material was 20 cents, it meant a 25-percent tariff. When the inflation made this worth 40 cents a pound the duty still remained 5 cents. It was still 12½ percent. So the whole thing was thrown out of gear.

Now when you spoke of this special legislation price fixed on tungsten, manganese, mercury, and other materials, that is the legislation that I have become interested in, and we had extended last year; isn't it?

Mr. HARDY. That's true, yes, but we are in great jeopardy right now. That is, the tungsten industry in that the domestic purchase program may expire within 2 years, and the Government should have a program to keep that essential industry in operation.

Chairman MALONE. Well, I have an idea that we might get it extended. You never can depend on it, but if we just allowed the 1934 Trade Agreements Act, Reciprocal Trade Act, to expire on June 12, 1955, and the regulation of that duty reverted to the Tariff Commission as an agent of Congress, and a flexible duty was regulated on a basis of fair and reasonable competition representing the difference in the wages and taxes here and the chief competitive nations in tungsten, you wouldn't need any special legislation, would you?

Mr. HARDY. No, we wouldn't. We would have the proper protection.

Chairman MALONE. Then what do you think about it? Do you think it should be extended or allowed to expire? I mean, the 1934 Trade Agreements Act?

Mr. HARDY. That should expire.

Chairman MALONE. Well, on recommendation No. 2 we recommend that Congress insure that the regulation of foreign trade conforms to the principles thus laid down in article I, section 8, of the Constitution, thus assuring the American workers and investors equal access to American markets.

You agree with that recommendation?

Mr. HARDY. That's right.

Chairman MALONE. That would mean the expiration of the so-called Reciprocal Trade Act. I am going to ask that in the end of my opening statement the introduction on page 1, the recommendations beginning on page 3, and the findings on page 5, and the list of critical materials on page 10, be included in the record. That will show the results of the work up to this date to be continued through resolution No. 271. The remainder of the report, 400 pages, is merely supporting data.

Do you have any further statement, Mr. Hardy?

Mr. HARDY. I would like to state that the University of Nevada is very much interested in a nuclear engineering program, which your chairman has advocated for the past 2 or 3 years, and, as he has stated on various occasions, we are doing the youth of our State an injustice by not having such a course at the University of Nevada. I believe that as long as our Government is using the State of Nevada as a laboratory in its various nuclear experiments, bombs and so forth, the Government or a proper agency should see that the University of Nevada is supplied with the necessary personnel and equipment to institute a nuclear engineering course.

Chairman MALONE. Along the lines of the reactor technology course we examined at Raleigh University that time of your visit East?

Mr. HARDY. I had the privilege of examining the reactor at Raleigh, N. C., with Senator Malone; also visited Oak Ridge and Brookhaven, and we could see the great benefit that would derive to this arid country if we could establish a reactor in some of our isolated mining areas.

I am very hopeful, Senator, that you will do all you can to aid the University of Nevada in obtaining the proper personnel and this reactor. The reactor can be a powerplant, necessarily, and part of its expenses could be paid by the production of plutonium.

Chairman MALONE. I think it can be brought about. I have thought so from the beginning, just as we thought that we could get this beneficiating project up here, improved methods of beneficiating your uranium ore and also the project on determining the effects of radiation dust on human beings and animals and plant life. You have to move one step at a time. I think we are ready now to take on this other project.

Another thing, I do not believe it is fair to the engineering students if you turn out engineers without some foundation in this nuclear energy. They certainly will not be competent to go to the top as power engineers, because within 5 years—5 to 10 years—you are going to see a large amount of nuclear power used in high-cost areas, in my opinion. I have said that for 5 or 6 years. You know they used to estimate that it would be 25, 35, 40 years before it would come in, but no one thinks that any more. You will recall, and you helped, I believe, Mr. A. M. Smith, who is now my administrative assistant. We were working on a small project in Eureka, and the AEC sent their representatives out 2 or 3 times, looked over their areas. There were none of us sold on it, but I guess we oversold it, because they are building a 60,000-kilowatt plant in Pittsburgh rather than a 20,000 one that we might have used out in Eureka. But I will say this: I think the work that you and Mr. Smith and others did here on that project helped the whole picture, because as soon as it is proved feasible in Pittsburgh, that is a going concern, a reactor, and the Army engineers are now working on a unit, flatcar unit that they could run into any Army

camp instead of running transmission lines and going to all that trouble, generate their own power, nuclear power, a plant just like a small diesel plant. That is along the order you just use it wherever it is necessary. Well, now, as soon as those experiments are carried out—and everyone is very hot on it now; they weren't when we started to talk about it; it was discouraging. I think you were with me the day we found the first man that took an interest in it. What was his name—

Mr. HARDY. Dr. Hafstad.

Chairman MALONE. And he did a lot of work on it, but now that they are all interested in it, even though we failed to get the reactor in Eureka, principally, as I say, because the one they are building is too large for us, as soon as it is proved feasible in any of these high-cost areas anyone can build them if the power demand is there; so I think we have done the work anyway. It would be nice if we could have had it out here for several reasons, used it in connection with the university, but we didn't get it. You can't win every time, I guess.

Mr. HARDY. When we do get it in this State we will accelerate the production of strategic and critical raw materials very materially for our country.

Chairman MALONE. One thing they are all convinced of, due to the evidence we have presented, and that is that the first use of these reactors will be in the mountains and deserts, high cost areas.

Do you have any further statement, Mr. Hardy?

Mr. HARDY. No, Senator.

Chairman MALONE. Well, your statement will be sent to you for corrections and accuracy and completeness, and if you have anything further at that time we will be glad to have it, and if you would send it in to us by December 1 we'd appreciate it.

That completes the work of the committee here, and I want to say for the record that the hearing here to advance the work under Senate Resolution 271, some of the evidence that we have heard here has been in the field of another subcommittee; but that evidence will be referred to the proper subcommittee when it is available, and the committee will stand in recess at the call of the Chair.

(Whereupon at 5:01 p. m., the hearing was adjourned subject to the call of the Chair.)

STOCKPILE AND ACCESSIBILITY OF STRATEGIC AND CRITICAL MATERIALS TO THE UNITED STATES IN TIME OF WAR

WEDNESDAY, NOVEMBER 17, 1954

UNITED STATES SENATE,
SUBCOMMITTEE ON MINERALS, MATERIALS, AND FUELS
ECONOMICS OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D. C.

The subcommittee met, pursuant to call, at 9:35 a. m. in room 224 Senate Office Building, Senator George W. Malone presiding.

Present: Senator Malone.

Present also: Jerome S. Adlerman, chief counsel; George B. Holderer, staff engineer; N. D. McSherry, chief clerk

Senator MALONE. The subcommittee will come to order.

We have convened the subcommittee this morning to continue the subcommitte's study in the field of critical materials. In 1953 the Senate passed Senate Resolution 143, which directed this subcommittee of the Committee on Interior and Insular Affairs, the Minerals, Materials, and Fuels Economics Subcommittee, to determine the accessibility of the critical materials in time of war and for our expanding economy.

As a result, the committee proceeded in its work over a period of approximately 10 months, heard 360 witnesses, held 58 hearings, and heard a cross section of the engineers, economists, and producers of the Nation.

There proved to be 77 of such critical materials so named by the Department of Defense.

On July 9, I, as chairman of the committee, by the direction of the full committee, submitted the report on Minerals, Materials, and Fuels Economics Subcommittee to the Senate which became then Senate Report 1627.

As a result of that report, the Senate passed a further resolution, Resolution 271, 1954, and it covers the same subject in a little more detail:

Resolved, That the Senate Committee on Interior and Insular Affairs, or any duly authorized subcommittee thereof, is authorized and directed (1) to (continue) investigate and study the accessibility of critical raw materials to the United States in time of war and for the expanding economy in time of peace; (2) to make a full and complete investigation and study of new developments and discovery of materials including synthetics which may be used as substitutes and replacements of critical materials, and further to study the progress of research programs, pilot-plant operations, processing and beneficiating methods of critical materials and minerals including fuels; (3) to make a full and complete investigation and study of the best means, methods, and devices to foster the greatest measure of self-sufficiency of critical materials that can be produced within the United States and the Western Hemisphere and to expand

and develop the strategic materials industry; (4) to make a full and complete investigation, and study the status of the stockpile program, its goals, and methods, and amounts of acquisition, storage, warehousing, and rotation programs; (5) to make a full and complete investigation and study the available fuel reserves of the United States and the Government regulations affecting such resources and to formulate and recommend a national fuel policy to assure maximum availability to meet the needs of the peacetime economy and for the national security in time of war; * * *.

As a result of the committee's work, the committee made 12 recommendations based upon 14 findings in the Senate report, Senate Report No. 1627, together with supporting data, and the entire part is a digest of the 11 volumes of testimony.

Conclusions upon which the recommendations were based:

First, of course, we had to determine what area would be available in time of war from which such critical materials could be secured. That was determined through hearing military strategists of outstanding reputation. It was determined to be the Western Hemisphere. It was determined that the Western Hemisphere could be defended and, as a matter of fact, testimony showed it is the only area that would be available in the first go-round in world war III, or whatever it happened to be named.

After we had started to win the war, and spread again our air control over other areas, they might again be available across major oceans immediately when the war started. We would be confined to the Western Hemisphere. Then we took over and through hearing engineers, economists, producers, the committee concluded that the Western Hemisphere could become self-sufficient in the production of everything they needed to fight in war and to live in peace, including replacements and substitutes, and of course engineers have always known the facts, but the report brought out very forcibly, often a substitute or a replacement is equal to or even better than the original material and sometimes you never go back to the original material at all.

So the two things that are important in the conclusions of the committee to date is that the Western Hemisphere is the only available area from which these materials can be secured in the first go-round in time of war and, second, that it can become self-sufficient in everything we need to fight a war or live in peace.

The Senate then directed the committee to continue its work and to do just what I have read, which is included in Senate Resolution 271.

The committee intends to go to South America just as soon as the present controversy on the Senate floor is settled. We do not know when that will be. We were scheduled to leave on the 4th of November and then the 14th and now it is in a state of flux until a date can be determined, based on the Senate work.

We are going there, of course, to determine what cooperation the nations of the Western Hemisphere, South America, Central America, and Mexico can give, whether or not they agree with what the committee has decided and, if not, to give us any suggestions they may have.

If they agree with it, as I have said, then what cooperation we can expect will be determined.

Today we have Mr. John Garrett, Research and Development Board, Department of Defense.

STATEMENT OF JOHN H. GARRETT, RESEARCH AND DEVELOPMENT BOARD, DEPARTMENT OF DEFENSE

Senator MALONE. Do you have a prepared statement, Mr. Garrett?

Mr. GARRETT. Yes, sir; this green covered statement.

Senator MALONE. You can proceed in any way you see fit. You know your subject. You have seen our report. You are more or less familiar with the work of the committee.

We called you, Mr. Garrett, because finally in any organization, no matter how many top men you have, you finally get down to the men that do the work. I like to do that. We had the engineers in the Bureau of Mines. Many of them have been studiously ignored for a good many years while reports of varying import were made. Many of us believe that the objective is established before the work is started. Many of these men spend their lives in certain areas of minerals. They were all heard and their testimony is a matter of record in the 11 volumes of testimony and a digest in the Senate Report 1627. So we have called you, Mr. Garrett, thinking that you have a wide field, and you not only have made certain investigations of your own but you should be familiar with the investigations that are now in the laboratories and the people that are conducting them.

You may proceed in your own way to give us any information you think would be interesting to the committee.

Mr. GARRETT. My name is John H. Garrett. I am assistant to Mr. Donald A. Quarles, who is Assistant Secretary of Defense for Research and Development. We have prepared this statement of some 41 pages. I don't know whether you want me to read this whole statement or perhaps skip through it and touch on some of the highlights and then the whole statement could go into the record.

Senator MALONE. It looks very interesting, Mr. Garrett. I think it would be very interesting if you just started to read it and make any explanation that you want to make, and give us an opportunity to bring out any further points that we think are necessary.

Mr. GARRETT. All right, sir.

ORGANIZATION OF DEPARTMENT OF DEFENSE RE CRITICAL MATERIALS

In the first page or two of this statement, I have outlined the organization of the Department of Defense in the materials field, showing which offices are responsible for which parts of the field. I thought that would be of interest in laying the background.

I have pointed out here two main functions that I feel the Assistant Secretary of Defense for Research and Development, in whose office I am, has in regard to critical materials.

First assuring that in the original development and design of military weapons and components, the most effective use is made of all materials, and second, performance on a continuing basis of research and development in the broad field of materials to obtain acceptable alternates which will obviate or at least mitigate our dependence on critical materials and strategic materials.

Senator MALONE. That statement is not too clear to the chairman. Naturally you are going to be dependent on critical and strategic materials, to a certain extent, but did you mean to determine where these materials can be secured satisfactorily within an area available to you?

Mr. GARRETT. I really meant there in that second statement to do research which will permit us to live within the quantity of materials that can reasonably be expected to be available.

Senator MALONE. Within an area you can defend?

Mr. GARRETT. That is right, sir.

Senator MALONE. Not necessarily within the United States, but within the area available to you in time of war?

Mr. GARRETT. Yes, sir. This will include the stockpile that had been built up plus the continuing sources of material that can be expected to come to this country or can be produced within this country under wartime conditions.

Senator MALONE. Or within an area you can defend, and which would be available during wartime?

Mr. GARRETT. That is right, sir.

It would include the maximum production that we could provide for from our own sources within this country, plus probably with only small losses, I would hope, materials from other countries in the Western Hemisphere. Of course, even there, where coast-wise shipping was involved, we know from the last war that we had quite extensive losses along the coast, and I presume we would have to expect some losses in a future war.

Senator MALONE. Of course, the losses would depend on the improvements in methods of defense and offense. That particular study is charged to your own department. You know more about it than anybody else.

The chairman was special consulant to the Senate Military Affairs Committee and the Secretary of War on Strategic and Critical Materials during World War II, and was very familiar with the losses suffered not only in the Caribbean area, but on shipments from Africa and other nations. Anything across a major ocean was prohibitive, of course, until you conquered the submarine problem.

There are many developments, of course, that are highly confidential, classified, where our coastline would be much more dependable. That is, transportation along the coastline would be more dependable than it was in the last war. But that remains to be worked out.

You know, of course, that the reason they are called critical and strategic is because this particular Nation does not up to now, or at least not at this time, produce enough for our own use for peacetime and wartime.

When you finally have a satisfactory substitute or a replacement in sufficient quantity for our use in wartime or increased production to that point, it is no longer critical or strategic.

We also developed in our hearings, I think the chairman did, that what we needed to determine was how large the stockpile should be in each particular category in connection with the going concern production capacity.

In other words, the stockpile plus the going-concern production would equal what you needed annually. And as your production increased going-concern production, your stockpile would be decreased. Perhaps when you have reached that point within the area you could defend, and producing at the rate needed, your stockpile would correspond to a working supply, such as all industries, like the steel business and all, maintain at their plant.

Of course, that is the objective, is it not?

Mr. GARRETT. I believe so, sir.

Senator MALONE. Go ahead.

Mr. GARRETT. We depend a great deal in our work in the office of the Assistant Secretary for Research and Development on the advice that we get from the most eminent men in all fields of science and engineering. In the materials field we have our technical advisory panel on materials, under the chairmanship of Dr. Jeffries. Practically all questions of a major nature are discussed with this panel before decisions are made, because we want to be sure that we have the benefit of all the best thinking in the country before we make a decision.

Senator MALONE. Dr. Jeffries is your own man in your own department?

Mr. GARRETT. No, sir. Dr. Jeffries is a retired vice president of General Electric Co. and is considered to be one of the outstanding metallurgists in the country.

Senator MALONE. What is his business now?

Mr. GARRETT. He is a consultant, still, to General Electric, and he is chairman of the board of the Battelle Memorial Institute at Columbus. He has no regular, full-time occupation.

Senator MALONE. How old a man is he?

Mr. GARRETT. He is in his early 70's now.

Senator MALONE. Who is the head of Battelle Institute?

Mr. GARRETT. Dr. Clyde Williams is president.

Senator MALONE. Do you know the history of the Battelle Institute?

Mr. GARRETT. In a general way.

Senator MALONE. It was organized by whom?

Mr. GARRETT. I think it was organized about 1923 or 1924, with an endowment which was left in the will of a Mr. Battelle, to conduct research in the fields of fuels and metallurgy, primarily. This organization has continued to grow under Dr. Williams' presidency over the years.

Senator MALONE. How long has Dr. Clyde Williams been president of it?

Mr. GARRETT. I am under the impression that he has been president since the origin of the organization. I might be wrong about that.

Senator MALONE. Do you know his background?

Mr. GARRETT. I don't know, no, sir; except that for some—if he has been there since the beginning, as I am sure he has, he has been with Battelle for some 30 years. What he did before that, I don't know.

Senator MALONE. Go ahead.

Mr. GARRETT. We also have available for advice the Materials Advisory Board of the National Academy of Sciences, the National Research Council, which was established some 3 years ago, nearly 4 years now, under contract with the former Research and Development Board, of which our office is the successor.

Senator MALONE. The National Research Council has been a very famous organization. Who is the Chairman of that Board now?

Mr. GARRETT. The Chairman of the Materials Advisory Board or of the Council?

Senator MALONE. The Council.

Mr. GARRETT. Dr. Bronk is President of the Academy, I believe, and I think that carries with it the head of the Council. The Academy and the Council, as I understand it, are parallel organizations.

Senator MALONE. That is the real name, the Academy of Sciences?

Mr. GARRETT. Yes, sir. It is more or less an honorary organization at the present time. The National Research Council is the active operating arm of the Academy of Sciences. Under their Research Council, there are a number of boards. There is, for example, a Quartermaster Advisory Board that was set up to work with the Army Quartermaster service. And, again, there is our Materials Advisory Board, which works both with us and with General Services Administration.

Senator MALONE. The Materials Advisory Board, is that a part of the Academy of Sciences?

Mr. GARRETT. That is a part of the Academy of Sciences. The Materials Advisory Board is under the chairmanship of Mr. John R. Townsend, who is materials and standards engineer for Sandia Corp. at Albuquerque. He is on leave from Bell Telephone Laboratories.

Senator MALONE. The Bell Telephone Laboratories have been responsible for a large amount of very valuable research in the national defense field, communications and all of that.

Mr. GARRETT. Yes, sir.

Senator MALONE. Would you mind furnishing for the committee's record a list of the members of the Academy of Sciences and then how it is divided in subcommittees or boards, and then the membership of the Materials Advisory Board?

Mr. GARRETT. I will be glad to do that.

(The list follows:)

NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL

MEMBERSHIP OF MATERIALS ADVISORY BOARD

Chairman: Mr. John R. Townsend, director, Materials and Standards Engineering, Sandia Corp., Albuquerque, N. Mex.

Vice Chairman: Dr. Francis C. Frary, technical adviser, Aluminum Co. of America, New Kensington, Pa.

MEMBERS

Dr. E. C. Bain, vice president, United States Steel Co., 525 William Penn Place, Pittsburgh, Pa.

Dr. E. K. Bolton, chemical director (retired), E. I. duPont de Nemours & Co., Wilmington, Del.

Dr. S. M. Cadwell, director, research and development, United States Rubber Co., 1230 Avenue of the Americas, New York, N. Y.

Dr. John Chipman, head, department of metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Mr. James H. Critchett, vice president (retired), Union Carbide & Carbon Research Laboratories, Orleans, Mass.

Mr. Alvin J. Herzig, president, Climax Molybdenum Co. of Michigan, 14410 Woodrow Wilson Boulevard, 14410 Detroit, Mich.

Dr. Matthew A. Hunter, dean of faculty emeritus, Rensselaer Polytechnic Institute, Troy, N. Y.

Dr. Zay Jeffries, vice president (retired), General Electric Co., 1 Plastics Avenue, Pittsfield, Mass.

Mr. Walter E. Jominy, chief research metallurgist, Chrysler Corp., Detroit, Mich.

Dr. C. K. Leith, emeritus professor of economic geology, University of Wisconsin, Sheraton Park Hotel, Washington, D. C.

Dr. D. H. McLaughlin, president, Homestake Mining Co., 100 Bush Street, San Francisco, Calif.

Dr. Lorrain J. Markwardt, assistant director, Forest Products Laboratory, Madison, Wis.

Dr. C. S. Marvel, professor of organic chemistry, University of Illinois, Urbana, Ill.
Dr. Robert F. Mehl, dean of graduate school, Carnegie Institute of Technology, Pittsburgh, Pa.
Dr. H. J. Osterhof, director of research, Goodyear Tire & Rubber Co., Akron, Ohio.
Dr. Albert J. Phillips, vice president, American Smelting & Refining Co., South Plainfield, N. J.
Mr. Oliver C. Ralston, chief metallurgist, United States Bureau of Mines, Department of the Interior, Washington, D. C.
Dr. Cyril S. Smith, director, Institute for Study of Metals, University of Chicago, Chicago, Ill.
Mr. E. C. Smith, chief metallurgist, Republic Steel Corp., Cleveland, Ohio.
Dr. John G. Thompson, chief metallurgist, National Bureau of Standards, Washington, D. C.
Dr. Hans Thurnauer, director of research, American Lava Corp., Chattanooga, Tenn.
Prof. Walter C. Voss, professor of building construction, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. Clyde Williams, director, Battelle Memorial Institute, Columbus, Ohio.
Mr. V. H. Schnee, executive director, Materials Advisory Board, National Research Council, 2101 Constitution Avenue, Washington, D. C.

Mr. GARRETT. Whenever we require rather intensive study of the situation surrounding any material, we make an assignment to the Materials Advisory Board, and that organization then assembles a special panel of experts in the particular field of the assignment. They make a thorough study of the situation, make a report to us, and then discharge that panel. We have had in the 3 years, or a little over, that the Materials Advisory Board has been in existence, 56 such studies made on various aspects of materials.

Senator MALONE. Would you mind listing those materials for the benefit of the committee?

Mr. GARRETT. I will be glad to do that.

Senator MALONE. You can submit a list, and together with the general results, just by a paragraph or two. Do not make it extensive, but just give us an idea.

Mr. GARRETT. Yes, sir.

(The list follows:)

INDEX OF MAB REPORTS

(NOTE.—(R) Restricted, (C) Confidential, (S) Secret, (BC) Business confidential.)

MAB–2–M	First Report on Titanium (C)
MAB–3–M	First Summary Report on Titanium (C)
MAB–4–M	First Report on Boron Steels (U)
MAB–5–M	First Report on Conservation of High Temperature Materials (C)
MAB–6–M	Boron Availability Report (C)
MAB–7–M	Second Progress Report (R)[1]
MAB–8–M	Report on Tungsten (S)
MAB–9–M	Columbium Report (S)
MAB–10–M	Manganese Report (R)[1]
MMAB–11–M	Report on Recommended Research Projects on Boron Steels (U)
MAB–12–M	Proposed Program on Basic Research in Extractive Metallurgy of Titanium (U)
MMAB–13–M	Low-grade Nickel Reserves and Processes for Recovering the Nickel (BC)
MMAB–14–M	Cobalt (S)
MMAB–15–M	Selenium (U)
MAB–16–M	Third Progress Report (R)[1]
MAB–17–M	First Report on Alternate Steels, BuShips Diesel Engine GM 12–278A (U)

[1] Declassified.

INDEX OF MAB REPORTS—Continued

MAAB–18–M	New Processes for Machining and Grinding (U)
MMAB–19–M	Bureau of Ordnance 3 Inch Caliber Twin Gun Mount (C)
MMAB–20–M	Preliminary Report on Germanium (S)
MMAB–21–M	Fourth Progress Report (C)
MMAB–22–M	Tantalum (S)
MMAB–23–M	Use of Rare Earths in Stainless Steels, Low Alloy Steels and Magnesium (C)
MMAB–24–M	Non-Magnetic Steels for Naval Use (R)[1]
MMAB–25–M	The Economic Comparison Between Mismanol and Alnico V (R)[1]
MMAB–26–M	Substitutes for Beryllium-Copper Alloys (U)
MMAB–27–MC	Fifth Progress Report (C)
MMAB–28–C	Q-Meter Testing as a Means of Augmenting Supplies of Capacitor Mica (U)
MMAB–29–M	Bureau of Aeronautics Navy Aircraft Gun Turret (R)[1]
MMAB–30–C	Production of Cobalt Supplies from Low Grade Ores (R)[1]
MMAB–31–C	Reconstituting and Synthetic Mica (U)
MMAB–32–M	Selection of Alternate Steels for Evaluation in Naval Armor (R)[1]
MMAB–33–MC	Sixth Progress Report (C)
MMAB–34–M	An Appraisal of Research and Development of Permanent Magnet Materials (U)
MMAB–35–M	Selection of Alternate Steels for Evaluation in 3-Inch Caliber 50 Naval Guns (R)[1]
MMAB–36–M	Bureau of Ordnance Ammunition Loader for the 3-Inch 50 Caliber Twin Gun Mount (R)[1]
MMAB–37–MC	Seventh Progress Report (C)
MMAB–38–M	Research and Development in Magnesium Alloys (R)[1]
MMAB–39–M	The Conservation of Nickel for Full Mobilization (S)
MMAB–41–M	Materials for Use in Gas Turbines (C)
MMAB–42–MC	Eighth Progress Report (C)
MMAB–43–M	The Small Arms Molybdenum Liner Program (C)
MMAB–44–MC	Natural Graphite (U)
MMAB–45–C	Possible Utilization of Phosphate Rock Slimes (U)
MMAB–46–C	Cyanite and Mullite Refractories (U)
MMAB–48–M	Possibilities for Nickel Conservation in Wartime (R)[1]
MMAB–50–C	The Potential Use of Vanadium (R)[1]
MMAB–52–M	Chromium (S)
MMAB–53–M	Testing of High Temperature Alloys (R)[1]
MMAB–54–C	Second Report on New Processes for Machining and Grinding (U)
MMAB–55–C	Conservation of Industrial Diamonds (U)
MMAB–56–M	Machinability of Ordnance Steels (U)
MMAB–59–M	The Recovery of Critical and Strategic Metals from High Alloy Scrap (U)
MMAB–60–M	Salt Water Valve Stems and Trim (U)
MMAB–61–C	The Status of Titanium Producing Processes (BC)
MMAB–62–C	Production of Cobalt from Low Grade Ores—Cobalt in the Ergani Copper Mines (U)
MMAB–63–MC	Ninth Progress Report (C)
MAB–65–M	Research and Development of Metals and Alloys for Low Temperature Applications (U)
MAB–66–M	Conservation of Materials in the Nike Missile (C)
MAB–68–M	Review of Titanium Research (C)
MMAB–69–C	Review of the Brown-Fisher Pilot Plant Proposal for Modified SO_2 Leaching Process for Manganese Ores (U)
MAB–71–C	Production of Manganese from Domestic Sources (supplement to MAB–10–M) (U)
MAB–76–M	Conservation of Materials in the Regulus Missile (C)
MAB–77–M	Conservation of Materials in the Sparrow I Missile (C)
MAB–82–M	Conservation of Materials in the Corporal Missile (C)

[1] Declassified.

Senator MALONE. Does this committee, when you ask for a special study, do they study the availability of these materials or are they merely studying the application of the materials, special alloys, and meeting certain conditions.

Mr. GARRETT. In some of our earlier studies that we asked them to make, we asked them to study everything connected with the material. By "everything" I don't mean it was an exhaustive study of sources of supply. For example, they didn't generally go into the reserves by districts, the sort of thing that the Bureau of Mines has information on. But to form a background of the study, on nickel, for example, they would look into the probable sources of nickel, in various parts of the world. Of course, they are not equipped to judge whether or not supply lines can be defended and that sort of thing. That kind of judgment has to be applied to their report by the Department of Defense. But they would indicate historically what the sources of nickel had been and then they would look ahead and try to see what things were being planned that would add to those sources of nickel. Then they would match against that the probable uses for nickel—I am using nickel just as an example—and then with that as a groundwork they would start from there and go into all the different things that nickel is used in, explore each one, and indicate steps they thought could be taken, whether it involved research and development or whether it involved application of knowledge already known, which could conserve the use of nickel in wartime in those various areas.

Senator MALONE. Or make more nickel available?

Mr. GARRETT. Or make more nickel available.

Senator MALONE. Let me ask you this question again:

Is this Academy of Sciences generally equipped to determine the possible expansion of production and various sources, or do they merely collect the data where such material has been produced, the history of it, and just assume that they can judge the future by the past?

Mr. GARRETT. No, sir. They try to look beyond that. They try to look at the possibility of expanding production, where the known ore bodies are, what are the chances of discovering more ore bodies. If it is a byproduct, such as selenium is a byproduct in the refinement of copper, they look at the extent to which selenium is now recovered from copper, so they can get a view as to where that can be expanded to get more.

They do look ahead into the possibilities. Of course, so much depends on Government policy as to whether possible expansions become realities. The Board cannot govern Government policies, and they, of course, can not forecast the Government policy. So there is, I think, a broad range that you can work in there between what would be done if no action were taken by the Government to promote expansion and what results you could get if you took major steps to expand domestic production.

Senator MALONE. Is the Government policy such as that laid down by President Truman of the United States, on page 376, when the President said:

I have today signed the Strategic and Critical Materials Stockpiling Act because it is important to the national interest that this Government have the power to acquire stockpiles. It is only because of the overriding importance of this purpose that I am able to overcome my reluctance to signing a bill which reaffirms the application to stockpile purchases of the provisions of title III of the

act of March 3, 1933 (47 Stat. 1520), known as the Buy American Act. Those provisions will not only materially increase the cost of the proposed stockpiles but will tend to defeat the conservation and strategic objectives of the bill by further depleting our already inadequate underground reserves of strategic materials.

We often wonder where these policies come from. We find that on January 10, 1944, the letter from the Secretary of the Treasury, then Mr. Morgenthau, to the President, undated and unsigned, on the Secretary of the Treasury letterhead, entitled "Memorandum for the President," and he says to the President:

I suggest consideration be given to a financial arrangement with the U. S. S. R. to provide her with $10 billion credits for the purchase of reconstruction goods in the United States, with provision for repayment to us chiefly in strategic raw materials in short supply in the United States.

1. The interest rate could be 2 percent, amortized over a period of 35 years. A schedule of repayments is attached.

2. The Russians have more than adequate means to assure full repayment. There are three principal sources from which she can obtain the necessary amount of dollars.

(*a*) Selling to us strategic raw materials which are in short supply in the United States because of our depleted natural resources. (See attached memorandum.)

(*b*) Russia will be able to develop substantial dollar assets from tourist trade, exports of nonstrategic items to the United States, and from a favorable balance of trade with the rest of the world.

(*c*) Russia has a stock of gold estimated at $2 billion now and is reported to be able to produce from $150 to $250 million per year. These gold resources can be used to pay her obligations to the United States to the extent that her other dollar sources are not adequate.

3. An important feature of this proposal is that we will be conserving our depleted natural resources by drawing on Russia's huge reserves for current needs of industrial raw materials in short supply here. We would be able to obtain a provision in the financial agreement whereby we could call upon Russia for whatever raw materials we need without giving a commitment on our part to buy.

4. This credit to Russia would be a major step in your program to provide 60 million jobs in the postwar period.

I will not read the remainder of it. It is all here and is a matter of record. There is listed here a reserve of domestic supply. Petroleum, a reserve of supply of 16 years, on the basis of 1939 consumption; on the basis of current consumption in 13 years we would be out of petroleum.

Manganese, 9 years, on the basis of 1939 domestic consumption, and on the basis of 1943 consumption 3 years will put us out of manganese. Tungsten, 23 years on 1939, and on 1943 consumption it is 3 years.

Manganese is 9 years and 3 years, tungsten 23 years and 3 years, zinc 17 years and 8 years, respectively, on the basis of consumption of 1939 and 1943, lead 7 years and 6 years, on the same basis.

For chromite there is no record. That is on a 1939 basis, and on 1943 basis it is less than 1 year.

Mercury, 3 years on the basis of 1939 consumption.

He goes on to say:

We could safeguard and conserve our strategic material reserves in postwar years which are now at a minimum level, by importing from abroad to meet ordinary annual production requirements. The U. S. S. R. has tremendous reserves of many raw materials which the United States will urgently require after the war. A reconstruction loan to the U. S. S. R. will give the means whereby we can conserve our natural resources for the next two generations, by utilizing Russian reserves.

Then it goes on to say:

The U. S. S. R. could provide substantial quantities of strategic raw materials for an annual basis within 5 years after the close of the war as indicated in the following table. Metals and metallic ores, manganese, tungsten, graphite, mica, chrome, mercury, platinum, copper, $80 million, within 5 years. Timber and wood products, $45 million. Petroleum, $50 million. Oils and oil cake, $10 million. Other industrial raw materials $15 million. Total, $200 million.

Then it goes on and sets down a repayment plan. My point is that the President adopted this plan for all intents and purposes, in his statement when he signed the 1936 stockpile act.

It is the policy of this Government—

as President Truman says in his statement—

the policy of this Government to work for international action to reduce trade barriers. We have proposed to other countries a set of principles governing trade and look forward to the successful conclusion of broad international arrangements embodying the essential principles of these proposals.

Pending the conclusion of such arrangements, it is the policy of this Government to avoid taking measures that will raise barriers to trade or prejudice the objectives to forthcoming discussions. We are asking other countries to follow similar policies.

Do you think that policy had anything to do with our dependence on other nations?

You mentioned the Government policies. Does it have anything to do with our dependence on other nations for these materials?

Mr. GARRETT. My view of that would be that under a free-trade policy industry will buy a great deal of foreign material where it can get it cheaper. I think that the national-security requirements, however, necessarily must modify such a free-trade policy.

As you say, if we allow the channels of trade to develop where they will during peacetime, these are generally or frequently not channels of trade which we must follow during wartime. I look at it somewhat this way: That you want to get your materials wherever they are cheapest in wartime in the same way that you do in peacetime. But to calculate the cost of materials in wartime, to the normal commercial costs, you have to add the cost of defending whatever supply lines you have to keep open.

This can be enormous in the case of some of the overseas sources of materials which make those sources completely impracticable in wartime.

Senator MALONE. What is the reason you can get this material cheaper from foreign sources than you can here, for example, when it is available in both places?

Mr. GARRETT. I think there are two reasons. One is that for many materials there are concentrated ore bodies that are scattered around the world, apparently on a completely chance basis. Many of the richest ore bodies are outside of the Western Hemisphere. It is naturally cheaper, other things being equal, to produce materials from a rich ore body than from a lean ore body. I think the other thing is that—I don't know just how to say it because it is a complicated thing. Let us just say the cost of production for whatever reason is frequently lower abroad in spite of our more efficient labor.

The foreign labor is sometimes so much cheaper that you can dig the stuff out of the ground cheaper.

Senator MALONE. Have you ever had any experience in production, producing properties of different kinds?

Mr. GARRETT. In production, but not in mining.

Senator MALONE. What kind of production?

Mr. GARRETT. Ordinary manufacturing.

Senator MALONE. What?

Mr. GARRETT. I was with the Army ordnance people before the war as a production engineer, working with companies, with ordnance contractors, ordnance arsenals and so on.

Senator MALONE. What were they producing?

Mr. GARRETT. Producing guns, fire-control equipment, ammunition, mainly.

Senator MALONE. Well, you are very familiar, of course, then, with the production of the Garand rifle, and the big 16-inch guns and all the rest of that during World War II.

Mr. GARRETT. Yes, sir.

Senator MALONE. I inspected the plants. But I had in mind more particularly the production of goods, consumer goods, and I had in mind more particularly being on the payroll end of it. Did you ever supervise or have anything to do with the production organization that was actually producing goods?

Mr. GARRETT. For the consumer market? No, sir.

Senator MALONE. Well, do you know or are you aware, have you ever studied this situation that probably there is no product on earth but what you can produce cheaper when you have wages that amount to from 10 to 50 percent of American wages, when the American machinery and American superintendents and American shifters are available to direct such labor?

Mr. GARRETT. I would assume that would be so.

Senator MALONE. Then what you actually mean is that what you are for is buying this material both in wartime and peacetime where you can get it the cheapest, where you have the cheapest labor, working conditions.

Mr. GARRETT. I didn't say I was for that, Senator.

Senator MALONE. You said we should buy the stuff there, I understand.

Mr. GARRETT. No, sir; I didn't say we should. I was describing what I thought was an existing condition.

Senator MALONE. Are you describing what you think is existing Government policy?

Mr. GARRETT. To tell you the truth, I am not sure whether this can still be considered Government policy. I think the national-security aspect of these things is considered by the Government much more strongly than it apparently was in the times when these letters were written. I would say that these do not represent exact Government policy today.

Senator MALONE. Would you favor a Government policy that President Truman outlined at that time in view of your knowledge now of national-defense requirements?

Mr. GARRETT. No, sir; I would not favor that.

Senator MALONE. Now we will turn just one page back and see where Mr. Morgenthau got this policy. You know, it has to come from some place. I may say for your benefit, because you are a very important man, or Mr. Quarles would not have sent you down here, that Government policy has, for many, many years, determined the

availability for these materials. They determine the availability in this way, certainly, because if you do not buy it, you have this free trade of which you have spoken, and direct competition with the low-cost labor of the world, with all of our machinery, guidance, and know-how.

I call them shifters and superintendents that are taken any place in the world. And you have all of the engineering talent in the United States available to go any place where the money can be made.

As a matter of fact, it was available to myself after my election to the Senate. And the type of men that industry sends into these places are not men who don't understand their business. They are men who understand their business. If you are going to build a textile mill in Africa or England, or you are going to build a mill for tungsten or anything else, it would be the best in the world, because it is the last one. Then with the men in charge of it that absolutely know their business from top to bottom, then the cost of the labor trained in routine work determines the cost of the product largely; does it not?

Mr. GARRETT. Yes.

Senator MALONE. On page 370, the reason we included in the record these letters is that there may be a difference of opinion drawn from it. I would be interested in yours.

Appendix 4, Harry Dexter White memorandum, proposed United States loan to the U. S. S. R., to Secretary Morgenthau, from Mr. White, dated March 7, 1944.

The following memorandum is in reference to your request that the feasibility of the extension of a large credit to the U. S. S. R. in exchange for needed strategic raw materials be explored.

Mr. Morgenthau requested this information:

Your opinion that such an arrangement might well be feasible appears to us to be supported by our study of the possibilities.

There is no need to read the rest of the thing because it is exactly what Mr. Morgenthau furnished to the President and the President announced it as the policy of this Government.

I do not need to go into the record of Harry Dexter White any more than Alger Hiss, I guess.

I know that the hard core of traitors to this Government, people who are trying to destroy it, are relatively small in number. But the people who want to hold a job, and that includes many college professors that want to hold honorary jobs or consultant jobs, and many engineers, I am sorry, and economists and others who want to be a part of the Government, and who do not realize where these things come from, become unwitting partners in carrying these things out.

I would not say Mr. Morgenthau was a party to Harry Dexter White's planning, but the language indicates it.

As a result, you now have your free trade policies so that business in this country cannot compete without Government subsidies.

Because of Government subsidies we are producing critical materials, and we would not need the Government subsidies if they had that protection that they used to count on as a part of the principles and policies of this Government.

That meant a duty that the Constitution of the United States in article I, section 8 calls it that makes up that difference, roughly, in the effective wages, taxes, and other costs of doing business in this

Nation and in the chief competitive nation on each product, which our Tariff Commission is very capable of determining.

It is flexible. And when the living standards of the chief competitive nation on a certain product rise, automatically the duty goes down.

If they have an equal living standard it automatically would arrive at the free trade that so many of our people seem to think is an objective without destroying our industry.

As a result of the policy enunciated by Mr. Truman, but embodied first in 1934 Trade Agreements Act, transferring the constitutional responsibility of the United States Congress to set the duties, imposts, and excises, and to regulate foreign trade to the Executive, meaning for all practical purposes the State Department, who is trying always to buy cooperation from the nations of the earth, we are now securing 900,000 tons annually of manganese from India, which is approximately one-half of our annual use. You are aware of that source?

Mr. GARRETT. Yes, sir.

Senator MALONE. And you know what I say is true?

Mr. GARRETT. Yes, sir.

Senator MALONE. Evidence shows conclusively that not a ton of it would be available within hours after the third world war is underway.

One witness put it a little more dramatically, and he said we do not make our steel in Pittsburgh, we make it in India where we get the manganese. You know it is impossible to make a pound of steel without manganese.

On columbium, this same witness said, we do not make our jet engines in Cincinnati, we make them in Algeria, where we get the columbium. It makes you feel pretty bad before you read the entire evidence and come to the full realization of what you have faced, what you would face in an all-out war.

That is the reason we printed Mr. White's letter, Mr. Morgenthau's memo to the President, and Mr. Truman's statement, It looks like Mr. Dexter White was a pretty effective worker.

I wanted to digress at that point where you brought in Government policies. Do you think that is good policy to follow on critical materials?

Mr. GARRETT. No, sir.

Senator MALONE. You wouldn't announce it yourself? You think it would be better to have something, some principle, that would protect the workingmen and investors of this country, would you?

Mr. GARRETT. I was speaking mainly from the national-security standpoint.

Senator MALONE. That is what I am talking about.

Mr. GARRETT. From the national-security standpoint, I think we need to develop available sources of materials. That is, sources that would be available during wartime.

Senator MALONE. Say that again.

Mr. GARRETT. I say from the national-security standpoint, I think we should have a policy of developing sources of raw materials which would be available during wartime.

Senator MALONE. I heartily agree with you. Now would you say that the best thing to do, then, would be to point out these things and have a subsidy on each one of them, and have someone in the Government determine what subsidy would be necessary to find these mate-

rials, or should there be a principle adopted under which investors could read the policy of the country and depend on it as a basis for investment?

Mr. GARRETT. I would be in favor of setting up conditions which would be favorable for industry to do the required work rather than to always have to have the Government in back of them doing the planning, as you have pointed out. Many times it is not a good situation.

Senator MALONE. I am very happy to hear you say that. I do hope you will study this situation. If you would just take the Constitution of the United States and read article I, section 8.

We changed it by a simple act of Congress and didn't even submit it to the people in this instance.

To me it is national suicide. If we wake up in time, we are lucky. From reading the papers every day, I don't think we have awakened yet. If you have probably noticed, we have dozens of people in Geneva now with the suggestions from every source. Every other nation in the world wants to divide up the markets of this Nation. They have the suggestion that we make a permanent free trade setup. You are familiar with the negotiations going on over there, are you not? Do you read the paper?

Mr. GARRETT. Yes, indeed.

Senator MALONE. Do you know about it?

Mr. GARRETT. In general terms, but I don't know about it in specific details.

Senator MALONE. Read this and you will know something about it.

Mr. GARRETT. I have already studied this. I have all 11 volumes of your report and find them very useful.

Senator MALONE. This will scare you out of your skin, if you read what is in it. The International Trade Organization was formed over there. What was it? It was a combination of maybe 55 nations. They would sit down once each year and divide the production of the nations of the world on the basis of "entitlements of consumption." Nobody ever knew what it meant.

We will supply the world. But it meant on a basis of population and need. Of course, we had 1 vote out of the 55. So not only our national defense was in danger, imminent danger, but our economy was in danger.

"Entitlements for consumption" was what they used. Wasn't that something? I will bet they never asked anybody as practical as Mr. Wilson about a word like that or it wouldn't have been in there. He never made a success out of the automobile business by giving it away.

Now, in your opinion on critical materials, we are in grave danger and you think it ought to be overcome through some method of building up your available sources in the event of war; you think it ought to be changed, that the policy ought to be changed to build up our own available sources of supply. Is that what I understood you to say?

Mr. GARRETT. Yes, sir.

Senator MALONE. Do you feel also it would wreck our economy, a policy carried out to that extent?

Mr. GARRETT. I think we are up against something broader than just that policy, and I think it is a question of socialism against a capitalistic economy.

Senator MALONE. What would you call international socialism if it wouldn't be dividing your markets with nations of the world?

Mr. GARRETT. I call that socialism and that is what we are up against, I think.

Senator MALONE. Do you believe in it?

Mr. GARRETT. No, sir; I do not believe in it.

Senator MALONE. Do you think a policy we followed for 75 years, staggered a little bit, but a general policy, of protecting the wage earners and investors in this Nation, and letting it depend upon the nations themselves when they raised their living standards would be better than the one we now have?

Mr. GARRETT. I hesitate to make a definite answer.

Senator MALONE. I do not say the one we now have. Let's say the one enunciated by Mr. Truman, Mr. Morgenthau, and Harry Dexter White.

Mr. GARRETT. I think theirs was wrong, because I think theirs was dictated by a Socialist philosophy. I think they were trying to impose a Socialist system on this country.

Senator MALONE. You know that GATT—General Agreement on Trades and Tariffs—that in this meeting being held now in New York City there are very prominent speakers in New York advocating more of the same. You have read that, haven't you?

Mr. GARRETT. No, sir; I have not read their speeches.

Senator MALONE. I will advise you to get this morning's New York Journal of Commerce and take the second section of it. It is full of it. It has been in the papers for the last few days. It is bad enough to destroy the economy of the country, but when you come to destroy our ability to defend ourselves, that gets down pretty close to the subject; does it not?

Mr. GARRETT. Yes, sir.

Senator MALONE. I like the way you approach it.

Will you go ahead?

Mr. GARRETT. In addition to the office that I am in, the Assistant Secretary for Research and Development, there are two other Assistant Secretaries who have materials functions in the Office of the Secretary of Defense. These are the Assistant Secretary for Applications Engineering and the Assistant Secretary for Supply and Logistics. Mr. Newberry is the Assistant Secretary for Applications Engineering and Mr. Pike is the Assistant Secretary for Supply and Logistics.

Applications Engineering works very closely with our office. The theory there is that the responsibility for new developments up through the prototype stage are in our office and the responsibility for getting those items into production, for doing a production engineering job on them, so that they will be suitable for mass production, is the responsibility of the Assistant Secretary for Applications Engineering.

Senator MALONE. Who are these Secretaries?

Mr. GARRETT. Mr. Newberry is the Secretary for Applications Engineering and Mr. Pike is the Assistant Secretary for Supply and Logistics.

The Supply and Logistics office, then, is responsible for all matters concerning quantitative requirements; that is, the amount of materials needed to meet estimates of mobilization schedules. Those are

calculated under the wing of the Assistant Secretary for Supply and Logistics.

None of these offices are operating offices. They are supposed to coordinate the work of the Army, Navy, and Air Force, to establish general overall policy. But the responsibility for doing the work, for getting the job done, is in the service departments—in the Army, Navy, and Air Force.

Senator MALONE. Let me ask you this: When you determine that a certain material is necessary in your business, who is responsible for seeing that the work is carried out to develop satisfactory alloys and those that will stand up under working conditions?

Mr. GARRETT. This is the responsibility of our office, of Research and Development.

Senator MALONE. You cover columbium, you cover titanium, and you cover other materials. One of the materials that we consider rather important to you because Mr. Robert Gross, Lockheed, and Mr. Donald Douglas of Douglas Aircraft, and the heads of other large and important aircraft manufacturing companies, said that it was impossible to develop a plane with a maximum range and carrying capacity without refueling without this metal.

If what these plane manufacturers say is true, it is a very important metal. Who was responsible for developing the necessary alloys and their durability for the aircraft industry?

Mr. GARRETT. My office is responsible in this field.

Senator MALONE. What progress are you making?

Mr. GARRETT. Well, we feel that we have made a tremendous amount of progress in the past year, but that much more remains to be done than has been done. We have recently established a new organization, a unique organization, to deal with titanium, simply because it was recognized. I would like to read one sentence from our statement here on titanium. It is on the bottom of page 39. I say there:

> We believe that the successful development and engineering application of titanium in this country will represent a major technological breakthrough. It opens up the possibility of military designs with performance characteristics that would be impossible of attainment with other known materials and could have an important bearing on the outcome of our technological race.

In view of this, we feel titanium occupies a completely unique situation today in the development of defense. To give it the attention it deserves, we have set up a steering group which is under the sponsorship of Mr. Quarles' office, with the objective of making sure that everything is done that can be done to get titanium into use at the earliest possible moment.

Senator MALONE. What is this group called?

Mr. GARRETT. It is called the steering group on titanium research and development.

Senator MALONE. Who is the head of it?

Mr. GARRETT. I am the chairman of the group.

Senator MALONE. Do you have a regular committee?

Mr. GARRETT. Yes, sir; we have representatives from the other two offices in OSD, Applications Engineering, Supply and Logistics, and from the Army, Navy, and Air Force.

Senator MALONE. That is all Government?

Mr. GARRETT. All Government.

Senator MALONE. Do you have any consultation or any advice from people who are attempting to use this metal?

Mr. GARRETT. Let me answer that this way: We have our regular advisory groups that I mentioned before which deal constantly with titanium. We never have a meeting of those groups that we don't discuss the current progress and the current situation of titanium. We also have a titanium panel in the Materials Advisory Board which is largely composed of the producers and the users of titanium.

Senator MALONE. Who are the Materials Advisory Board?

Mr. GARRETT. There again that is the group under the National Academy of Sciences set up to advise us on specific materials problems.

Senator MALONE. You are furnishing the membership?

Mr. GARRETT. I am furnishing the membership of that group, and if you like I will furnish the membership on the titanium that they set up also.

(The information referred to follows:)

MATERIALS ADVISORY BOARD

PANEL ON NEW PROCESSES FOR MACHINING AND GRINDING

Earl E. Schumacher, Bell Telephone Laboratories, chairman
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H. P. Chandler, Bureau of Mines, Department of the Interior, liaison representative
Miss M. M. Dotye, Miscellaneous Metals and Minerals Division, NPA, liaison representative
N. C. Fick, Office of Secretary of Defense (Research and Development), liaison representative
P. M. Hall, Metal Working Equipment Division, NPA, liaison representative
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J. H. Williams, Office of Industrial Equipment, Office of the Secretary of Defense, liaison representative
H. E. Witt, United States Air Force, liaison representative
Dr. Julian Glasser, MAB staff consultant

TITANIUM RESEARCH PANEL

Dr. E. C. Bain, vice president, United States Steel Corp., chairman
Dr. H. K. Adenstedt, staff metallurgist, Lycoming Spencer Co.
Brank B. Bolte, chief of engineering laboratory, Northrop Aircraft, Inc.
C. I. Bradford, vice president and director of operations, Rem-Cru Titanium, Inc.
Dr. Marshall Brown, assistant director, engineering research laboratory, E. I. du Pont de Nemours & Co.
Lee Busch, director of research, Mallory-Sharon Titanium Corp.
J. C. Chyle, director of welding research, A. O. Smith Co.
E. O. Dixon, vice president in charge of research and metallurgy, Ladish Co.
D. C. Goldberg, head, metallurgical secretary, Westingshouse Electric Corp.
J. L. Goldthwaite, critical materials engineer, Allison division, General Motors Corp.
Dr. Bruce Gonser, assistant director, Battelle Memorial Institute
H. Hanink, manager, metallurgical engineering division, Wright Aeronautical Corp.
Dr. S. A. Herres, technical director, Titanium Metals Corp. of America
R. B. Johnson, Jr., engineer, General Electric Co.
J. S. Martin, chief research engineer, Republic Aviation Corp.
A. J. Pepin, quality and research manager, Wyman-Gordon Co.
L. W. Smith, head, metallurgy secretary, Cornell Aeronautical Laboratory.
L. P. Spalding, chief research engineer, North American Aviation Corp.
R. H. Thielemann, development engineer, Pratt & Whitney Aircraft Corp.
O. A. Wheelon, mechanical engineer, Pacific Palisades, Calif.
V. W. Whitmer, assistant chief metallurgist, Republic Steel Co.
Dr. W. J. Harris, Jr., MAB staff metallurgist

Senator MALONE. What would you consider your status in this investigation? Have you arrived at any satisfactory alloy for making engines and airframes and for the particular use that these companies manufacturing jet engines and airframes want to use it for or are using it at the present time? What is your idea of it?

Mr. GARRETT. The alloys that are on the commercial market today are by and large the same ones that were available a year ago. They have ultimate tensile strength ranging up to 150,000 to 160,000 pounds per square inch.

Senator MALONE. How does that compare with steel, aluminum and other metals that might be displaced?

Mr. GARRETT. The strongest aluminum alloys used in aircraft construction run around 80,000 pounds per square inch ultimate tensile strength, but of course, they are only something like two-thirds as heavy as titanium. So on a comparative basis the 80,000 p. s. i. aluminum alloy would be comparable to 130,000 to 140,000 for titanium. You might say they were practically at a standoff with today's commercial alloys. However, we have in a very advanced stage of development and now in an experimental production on full scale, several improved alloys that show promise of reaching 180,000, or higher, pounds per square inch.

I feel that the prospects are that in the not-too-distant future these high-strength titanium alloys will give aluminum a real run for its money even in ordinary room temperature applications.

Senator MALONE. Suppose they are equal and fit into the jet engine and airframe construction. If they were equal in tensile strength, where would they fit in?

Mr. GARRETT. The earlier applications of titanium are bound to be in the places where aluminum won't do the job. Even if titanium were only equal to aluminum, the tendency would be to use aluminum where it could be used, simply because we have so many years of experience with aluminum that we know exactly what to expect.

Titanium is new. The aircraft engineers are not yet too confident in all the properties. We are still running into occasional difficulties with titanium. So I think if they were equal, you would still find the preponderance of use in aluminum.

Titanium then will be used first where aluminum won't do the job and that is where the temperatures start getting up above 250° or 300° F. Titanium still keeps its strength and aluminum starts dropping off very fast at those temperatures.

Senator MALONE. At what temperature does the titanium start to fail, present alloys?

Mr. GARRETT. Titanium is good with present alloys up to around 800°. It starts losing a fair proportion of its strength, and it doesn't look as though it is very promising beyond 900° to 1000°. In other words, it is not a super high temperature alloy.

Senator MALONE. How does the weight-strength ratio compare with aluminum, stainless steel, and other materials that might be used in place of it or that might be used as a substitute for it?

Mr. GARRETT. The highest strength aluminum, with strengths of around 80,000, the highest strengths stainless steels with strengths up around 180,000 or a little higher, and the current commercial titanium alloys of 140,000 to 150,000 are almost a standoff on a strength-weight basis.

Senator MALONE. With stainless steel?

Mr. GARRETT. Yes, with stainless steel, because the strengths go up almost proportional to the weights. But as titanium gets a little better, as the improved alloys come out, there will be a very definite strength-weight advantage for titanium. I might correct that slightly. I think today's commercial alloys have a definite margin of advantage over stainless steel, because stainless steel is a good 40 percent heavier than titanium, and it is perhaps 20 percent stronger, so that the strength-weight advantage is in favor of titanium today.

Senator MALONE. Now, in your opinion if titanium alloys do reach 180,000 pounds per square inch tensile strength, which, you think, will in a reasonable time, then there would be no comparison whatever.

Mr. GARRETT. That is right.

Senator MALONE. You don't think stainless steel is going to get any greater?

Mr. GARRETT. No, as far as I know we have gone as far as we can with stainless steel. There might be a slight improvement.

Senator MALONE. What is the time element involved in the proving of titanium alloys?

Mr. GARRETT. Well, we have had titanium flying now for probably a year and a half in the F–100, and we are getting a lot of good experience. This is with some of the earlier and poorer alloys. I would say as each new alloy comes out of the laboratory it will take a year

or two to get adequate service experience with it. I think for those just coming out now it will be another 2 years before we are completely confident and have it in wide scale use.

Senator MALONE. At what point does the stainless begin to diminish in strength as far as heat is concerned?

Mr. GARRETT. Around 1000°, 1100°, or possibly 1200°.

Senator MALONE. There wouldn't be much difference in the heat resistance of the two metals if the titanium increases as you think it will.

Mr. GARRETT. Steel will be good 300° or 400° higher.

Senator MALONE. Not if you say titanium will come to 1000° or 1100° and the other is at 1200°.

Mr. GARRETT. Titanium is at about 800°. I am not sure that the alloys resistant to high temperatures will be the super high strength alloys. They may have a slightly lower strength level.

Senator MALONE. What is the time element involved, in your opinion, the way you are proceeding now, in obtaining satisfactory titanium alloys that will have this advantage?

Mr. GARRETT. I think these 180,000 pounds per square inch strength alloys will be on the market, available for wide commercial use, if we don't run into unexpected trouble, within the next year or so.

Senator MALONE. Within the next year?

Mr. GARRETT. Yes.

Senator MALONE. You agree then that you can't make the maximum speed, the maximum range plane without this titanium metal?

Mr. GARRETT. Yes, I agree.

Senator MALONE. It would appear, then, that there is no metal at this time that fulfills that part in the setup of manufacturing planes?

Mr. GARRETT. That is right. Titanium has certain unique properties that no other metal will meet.

Senator MALONE. I was interested in a rumor I heard not very long ago that there was a steel developed as an alloy that would be of even greater use in this field than titanium.

Mr. GARRETT. There has been a new steel, that is, it is relatively new, within the last few years, the precipitation hardened stainless steels. These are the ones I was talking about when I indicated the high strength steels with strengths of 180,000 to 200,000 pounds per square inch. That is the new steel.

Senator MALONE. That is the maximum dreamed of in steels now?

Mr. GARRETT. There is another class of steels which are not stainless which some of the aircraft companies have been experimenting with. These are high alloy engineering construction steels capable of being heat treated to an ultimate tensile strength in the neighborhood of 280,000 pounds per square inch. These steels would not be interchangeable in many applications with titanium because, since they derive their strength from heat treatment, they lack the property of retaining these high strengths at elevated temperatures. Also, they are not corrosion resistant. It is also not certain yet that their fatigue strength and ductility would be adequate except for specialized applications.

Senator MALONE. And titanium, you think, will in the weight-strength ratio, surpass anything that is even thought of in steels?

Mr. GARRETT. I think so.

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Senator MALONE. I wanted to be sure of that. We even had a rumor one time after our first hearing on titanium that we had too much titanium. Of course, many of us knew why that was. As you know, we are manufacturing maybe two-thirds of the production now of titanium in Henderson, Nev. That is annual production. There is about one-third of it over in New Jersey with the Du Pont Co. The Titanium Corp. is in Henderson. I was interested too that they testified in a hearing we had a few weeks ago in Henderson that they had now reached their 10-ton production and had also reached specifications. Is that your estimate of it?

Mr. GARRETT. That is my understanding. I think all titanium producers are turning out far better metal today than they were a year ago.

Senator MALONE. We determined in our hearings a year ago out there, or a little more than a year ago, that their 10-ton a day contract that they had had for a couple of years, that they were only manufacturing 3 or 3¼ tons a day, and none of them had specifications. So there has been some progress since the committee started.

Mr. GARRETT. There has been real progress.

Senator MALONE. What about the titanium scrap. Somebody suggested in the testimony there that great progress was being made in reclaiming scrap and there was a possibility of almost doubling the available production, available through actual use, through the saving of the scrap.

Mr. GARRETT. This is true, I think. I think all of the companies are now using most of the scrap that they generate within their own plant. That is, Rem-Cru at their production plant at Midland has ingots that they have to crop, has various analysis heats that they can't use. A good deal of scrap is produced. This they can reclaim and remelt right there.

The president of Rem-Cru was telling me the other day that currently they are melting about 35 percent scrap.

Senator MALONE. Who is the president of Rem-Cru?

Mr. GARRETT. His name is Bradford.

Senator MALONE. You think, then, in the definitely foreseeable future that most of this scrap even created through the shaping of titanium manufacturing, and the creating of titanium shapes, will be usable, and that in the foreseeable future most of it can be reclaimed?

Mr. GARRETT. I would hope so, that the machining losses, the scrap that you get during the machining of titanium, that much of that can be cleaned and fed back.

There was a letter on that that came to my attention the other day from one of the west coast airplane companies, in correspondence between them and Rem-Cru, indicating that Rem-Cru was willing to offer, I believe something like $1.50 a pound for scrap, which I thought was a pretty good price. But the difficulty seemed to be that the scrap had to be treated in a very special way and then canned in sealed containers for shipment back to Rem-Cru and this made it rather expensive to handle. The west coast company said that they couldn't profitably handle it at that price.

Senator MALONE. It would be a good indication, anyway, that they are taking some interest in it.

Mr. GARRETT. Yes.

On this scrap situation, it had seemed to us in the steering group that this represents one possibility of bringing the price of titanium down. We realize that every company has an economic incentive to use all the scrap they can, because if they can use scrap that costs only $1.50 a pound instead of some that costs them nearly $5, they are going to make more money on their titanium.

So there is quite an incentive to business to use all of the scrap they can.

Senator MALONE. Is your investigating committee encouraging research along these lines?

Mr. GARRETT. That is what I was getting to. We feel, nevertheless, that it is possible that the development of ability to use scrap could be expedited by some Government financial support to the companies working in this field. We are now asking the Materials Advisory Board, again, to set up a special panel of experts in that particular field to indicate where support by the Government would be likely to accelerate this ability to reuse scrap.

Senator MALONE. Do you have authority to extend that support without further legislation in case you consider it necessary?

Mr. GARRETT. We have, yes, in the Department of Defense a research and development emergency fund that is under the control of the Assistant Secretary of Defense for Research and Development. We are counting on using this emergency fund to accelerate the titanium program for the current fiscal year, and then for the coming fiscal year provision will be made in the 1956 budget of the Department of Defense for the necessary additional funds.

Senator MALONE. Have you made any study as to the amount of titanium that they could use advantageously for national defense if it were available?

Mr. GARRETT. Studies have been made by the Department of Defense. They have not been under my sponsorship directly, but I am somewhat familiar with them.

Senator MALONE. Whose sponsorship are they under?

Mr. GARRETT. Mr. Pike's sponsorship, Assistant Secretary for Supply and Logistics.

Senator MALONE. What are his initials?

Mr. GARRETT. Thomas Pike.

Senator MALONE. What are his conclusions?

Mr. GARRETT. I might go back into the history of a little bit of these requirement studies. I think it might be of interest. About 3 years ago, the Research and Development Board started taking an intense interest in titanium and at that time we were having a great many problems that are now being overcome, problems with nonuniformity in quality of the material. Poor material was being turned out. After studying the thing, it was the conclusion of our people that what was needed was, more than anything else, expanded production in order to give the companies making titanium the experience and the skill needed to know how to turn out good metal.

Senator MALONE. Is that about the time that you notified or at least that you concluded and so recommended that 35,000 tons annually be produced?

Mr. GARRETT. That is correct. That is 2 years ago this summer.

Senator MALONE. You recommended that amount to the Office of Defense Mobilization or whatever you call that committee that had the job at the time?

Mr. GARRETT. That is right. This was done 2 years ago in August, I believe.

Senator MALONE. When you recommended 35,000 tons?

Mr. GARRETT. We recommended 35,000 tons within 3 years. We thought it should be built up to that level within 3 years and that would mean by next year.

Senator MALONE. By 1956?

Mr. GARRETT. 1955.

Senator MALONE. 1955?

Mr. GARRETT. Yes.

Senator MALONE. Let me ask you, is that still your conclusion, that that is all you need?

Mr. GARRETT. This was not our conclusions as to what the ultimate level would be. This was only our conclusion that this would be a point on a rising curve that we ought to aim for within 3 years, and then the curve would presumably go on rising after that.

Senator MALONE. If you found suddenly that you needed four times that amount, would that change your calculations at all, in point of time?

Mr. GARRETT. There, again, I think it is all a question of timing. I personally would not be surprised to see our production reach 500,000 tons within the foreseeable future. But it would be very difficult to put an exact time on it.

Senator MALONE. I am not talking about you putting an exact time on it. I am talking about you being the one most interested to recommend what you need. What do you need now, if you had it, if you could have it tomorrow? That is, of a usable nature, like the quality they are manufacturing now?

Mr. GARRETT. How much do we need today?

Senator MALONE. If you are going to build the planes that you need, and the number that you need—I suppose you cooperate with the rest of your organization, and know you need planes that will fly faster, will fly farther, and carry a greater amount of bombs or men than you are now carrying.

Mr. GARRETT. That is perfectly true. The planes that need titanium are just coming into production today. There are, of course, production schedules set up for those planes. Those are the bases for the calculation of requirements.

Senator MALONE. Is that still 35,000 tons annually?

Mr. GARRETT. I have not seen the requirement figures, but my understanding of them is that the latest calculation, which I think was made a year ago, gives a requirement based on peacetime production for 3 years from then, which would be a couple of years from now, of about 35,000.

Senator MALONE. The thing that mystifies the chairman is that the people that manufacture the planes say you need four times that amount now, and they have the planes on the drafting board and don't dare take them off the drafting board because they know they would be out of titanium before they turn around.

Mr. GARRETT. I think this is true, and this goes back to the old chicken-and-egg proposition.

Senator MALONE. I have heard that so often. This is the chicken we are looking for now. We have the egg. The egg is there and the boys now know how to make it.

Mr. GARRETT. I think there are two things that are needed, sir. We are getting down to the crux of this matter that has been causing a great deal of consideration for the past 2 or 3 years in the Defense Department, and that is just what does need to be done to get titanium into production. I think there are 2 things, and I think what you mentioned is 1 of them, that there has to be enough titanium in sight so that the designers will design it into their planes with some assurance of being able to get it.

Senator MALONE. They have designed it into the planes, but they don't dare take it off the board.

Now, you know now how much they need to make the planes that you need. I am not sure you think you need these sonic-speed bombers.

I don't know if you think you need them. I know the planemakers think you need them, and I know we think you need them. Do you think you need them?

Mr. GARRETT. Yes; I am wholly convinced that we are going to need thousands of tons of titanium. But I don't——

Senator MALONE. What I am trying to ask you now, and let us just confine it to that for the moment, Why wouldn't you just estimate that amount that you need as of today? Of course, no one could produce it for you tomorrow, but they would have a target to shoot at. There is no target now. The chairman of this committee has been very perturbed about it.

Mr. GARRETT. Well, let's talk about it a little bit. Let's review if we could for a minute, how the requirements are made up.

Senator MALONE. I wish you would, because this is most important, in the opinion of the chairman.

Mr. GARRETT. First of all, I will have to say that I am not nearly as closely associated with the calculations of requirements as I would like to be.

Senator MALONE. Who is? Let's stop at this point. We want to get a witness down here that is not only closely associated with it but is responsible for it, even if it is Mr. Wilson. We will have him back down here.

Mr. GARRETT. We can start with Mr. Pike. It is the responsibility of his office, the office of the Assistant Secretary for Supply and Logistics——

Senator MALONE. Does he keep that responsibility in his office or does he put the finger on somebody to study it?

Mr. GARRETT. He has people on his staff, and the people there——

Senator MALONE. Name them.

Mr. GARRETT. I will name those that I can. He has 2 or 3 echelons of supervision that I don't know, but then you finally get down to Mr. Carl Rolle.

Senator MALONE. Will you for the benefit of the record name these echelons that this information filters through?

Mr. GARRETT. Starting at the bottom rather than at the top?

Senator MALONE. Starting at the top.

Mr. GARRETT. You have Mr. Pike.

Senator MALONE. Esprit de corps in an organization does not start at the bottom, it filters down from the top. Who is between Mr. Pike and who is the assistant?

Mr. GARRETT. Mr. Carl Rolle is the man who is head of their materials work.

Senator MALONE. Who is the Assistant Secretary charged with it?

Mr. GARRETT. The Assistant Secretary is Mr. Pike.

Senator MALONE. Who is between Mr. Pike, then, and the man down here that you say, after you skip several echelons, is responsible?

Mr. GARRETT. Mr. Rolle is in charge of the Materials Section in Mr. Pike's office.

Senator MALONE. He is directly under Mr. Pike?

Mr. GARRETT. No, he has these 2 or 3 individuals in between.

Senator MALONE. What do they do?

Mr. GARRETT. They have charge of divisions and deputies to Mr. Pike and so on.

Senator MALONE. What do the divisions do?

Mr. GARRETT. I think I can tell you the main people involved, but I am not familiar with all of the names in the organization. I can get those for you.

Senator MALONE. Don't skip anybody. I don't want a missing link. I want to know who is involved.

Mr. GARRETT. Yes, indeed.

Senator MALONE. Now, do you know what they base their calculations on?

Mr. GARRETT. Yes, sir. I was getting to that. Under Mr. Rolle is Dr. Timothy May, who is in charge of light metals, and titanium falls in his bailiwick.

Senator MALONE. How many metals is he responsible for?

Mr. GARRETT. Primarily three, which are magnesium, aluminum and titanium.

Senator MALONE. There is not a suspicion, but just kind of an idea that creeps in that some of the delays on some of the metals that replace other metals may be due to the people who are interested in the metals being replaced. Would you have any idea on that subject? It has been done, you know. It has been known to happen in the Government.

Mr. GARRETT. I know there is not in my organization. It is difficult for me to speak of another organization, of course, along that line, but I will say that I have seen no evidence of this.

Senator MALONE. Well, are these men in your position and higher aware of what we might run into if we don't have these planes when the time comes? Are you aware of speeches being made on the Senate floor that we must warn Russia that she can't come beyond a certain point, and yet you don't have the planes to do it?

Mr. GARRETT. I think the top people in the Department of Defense are certainly more aware of the titanium situation than they are of any other materials problem.

Senator MALONE. Who are some of them, so we can have them here.

Mr. GARRETT. You have had them. Mr. Wilson and Mr. Anderson.

Senator MALONE. Don't they charge anybody with the responsibility of this business?

Mr. GARRETT. As I said——

Senator MALONE. If they do, what do these people do? How do they spend their time?

Mr. GARRETT. The thing I am trying to bring out is that this question of requirements is the one area of importance in the titanium field that is not the responsibility of my steering group on titanium. I think we could do a better job if it were, but it just——

Senator MALONE. But it is the responsibility, definitely, of Mr. Pike?

Mr. GARRETT. That is right.

Senator MALONE. We will get Mr. Pike for tomorrow. We must have people who know what they are talking about.

Now you may go ahead. Would you say this applies to all of these other metals that you are responsible for?

Mr. GARRETT. I can follow that on down into the departments, if you would like me to, but if you are going to have Mr. Pike tomorrow, he can speak with authority.

Senator MALONE. You go right ahead and follow it down through.

Mr. GARRETT. Going down, then, the Office of Assistant Secretary for Supply and Logistics, Mr. Pike's office, sends out a letter to the Army, Navy and Air Force, and says, "Will you calculate your requirements for titanium over the next 5 years based on certain assumptions, and these assumptions are such things as the price will average $10 a pound, say, and the metal will be available. That is, you don't need to say you won't have a requirement because you won't have the metal. For this calculation, assume the metal will be there and assume the quality will be adequate and that it will have such and such properties. How much would you then use?"

That is the nature of the request that goes to the Army, Navy and Air Force.

This then goes to the Director of the Industrial Resources in the Air Force. I might speak just of the Air Force from here on, because most of the requirement is theirs.

Senator MALONE. Who is he?

Mr. GARRETT. There is a brigadier general there. I can't remember his name at the moment. But the person it goes to there, who is in charge of materials, is Col. R. W. Green, who is a member of my steering group from the Air Force.

Colonel Green then sends it on out to Wright Field and it goes to what used to be General Metzger's shop, and General Metzger, were he still there, would be in charge of calculating the requirements.

He goes out then to all the different aircraft and engine companies and poses the same question to them and they come back with the answers, and his shop compiles them all and sends them up the line, and that is the requirement that comes out.

Senator MALONE. Would you do something which is impossible for me to do? Start with Mr. Pike if he is the one where it starts, or wherever it does start, and trace it until it goes to Mr. Green who sends it to Wright Field and then back to Mr. Green and up through the steps until it finally gets back to Mr. Pike. Does it?

Mr. GARRETT. Yes.

Senator MALONE. Mr. Pike writes the letters to Mr. Fleming?

Mr. GARRETT. That is correct.

Senator MALONE. What would you do, knowing what you now know, if you were charged suddenly with the responsibility of the information going to Dr. Fleming?

Mr. GARRETT. I would follow each one of the major parts of that requirements schedule. I suspect that 90 percent of these requirements could be traced to 15 or 20 companies, and I would follow those requirements individually, of those 15 or 20 companies, so that as soon as a requirement that a company had sent in—when it was at the point where they had to order the titanium to meet those requirements—I

would find out why they were not ordering what they said they were going to.

Senator MALONE. Let's assume you could get it by ordering, it. You know the performance you want on your plane, you know what this thing is going to do. You are putting the pressure on to get these alloys.

Now I understand they have this stuff down to 140 or 150 hardness, and they have other specifications they have fulfilled, that you can do anything with this sponge that is necessary to be done. The alloy field and shaping field is your bottleneck. General Services Administration is letting the contracts, and we find no fault with that, but they are still shooting at 35,000 tons a year.

So what would you do if you just suddenly were in charge of it and knew you could get it by ordering it?

Mr. GARRETT. I think there is one misconception that should be cleared up.

Senator MALONE. What is it?

Mr. GARRETT. That is the way in which airplanes are bought by the Department of Defense. The Air Force goes out to a bunch of airplane companies and says, "We would like an airplane to meet these performance specifications."

Then all the different companies design their concept of an airplane to meet those specifications and requirements. The Air Force then considers all of these designs and selects the one that they think comes the closest to meeting it.

Then they have a few of them built and they try it out.

If it works out, then they give the company an order to go ahead into production. The selection of the material that goes into the plane is wholly the company's. The Air Force has nothing to do with it. The company has the responsibility for designing the airplane and guaranteeing the performance. When the airplane is released for production, again the Air Force has nothing to do with what materials go into the plane. That is up to the company. They decide what goes in and they order the materials.

So the Air Force and the Government cannot order this material for the airplane companies. It is wholly up to the company to order whatever material they want, and the Air Force cannot tell an airplane company, "You will put titanium into this airplane." They cannot do that.

Senator MALONE. Why did you order 35,000 tons to start with?

Mr. GARRETT. We have not ordered 35,000 tons. All we have done is tell the Office of Defense Mobilization, "We estimate that these airplane companies working on their own initiative will voluntarily order 35,000 tons of titanium."

That is all we told them.

Senator MALONE. Do you have any idea of what they would order now if they thought they could get it?

Mr. GARRETT. There, again, I am speaking of an understanding of what others in the Department of Defense have done, over whom I have no responsibility, but my understanding is that the latest calculation was made about a year ago and it still came out at about 35,000 tons, and that they are today reviewing this to find out whether it is the same or different.

This is all 3 years. It is all a 3-year time schedule. The 35,000 tons does not mean that the airplane companies wouldn't use more 4 years from now. They will. Certainly the trend will keep on going up.

Senator MALONE. Do you have any evidence that they wouldn't use more than that now if they had it?

Mr. GARRETT. Only their own statements.

Senator MALONE. They told you they wouldn't?

Mr. GARRETT. They told us they wouldn't. That is right. Our requirements are based only on what the airplane companies and engine companies have officially told us.

Senator MALONE. That, of course, stymies us a little bit.

Mr. GARRETT. That is right. That is our difficulty. I think the thing is that the testimony before this committee does not have a time tied to it; whereas, what they tell us does have a time tied to it, and I believe that is the difference. The 150,000 figure might be 4 years from now or it might be 5 years.

Senator MALONE. They said they could use it now. That is their testimony. And knew they were going to need it so that they could take these planes off the drafting board and start making them. There is something that does not make sense. You help me do it. I am going after that. So I would advise you to start from the other end.

Mr. GARRETT. I think this would be a very helpful end, to find out where this difference comes in.

Senator MALONE. All right. Go right ahead.

Mr. GARRETT. I might read one paragraph from page 3 of this statement which outlines the basic principles or attitude that the Department of Defense takes toward conservation.

The basic principles of the Department of Defense materials conservation program may be briefly summarized as follows. Conservation is not a compartmentalized function, but an aspect of every job responsibility in the Department. It is a frame of mind, and an attitude, expressed broadly as the balanced, prudent use of the entire resource pattern available for defense.

The focus of the program is first upon mobilization readiness; and secondly, upon redundancy of current impacts of defense programs upon the national economy.

The procedures of conservation are based not on nonuse but upon the best use of each pound of each material.

The program emphasizes most the conservation of those materials most likely to restrict essential production in time of emergency, it emphasizes conservation of those materials and in items in which they find their heaviest use.

Then I go ahead in this statement and pick out a few areas of military equipment that are some of the heaviest users of strategic and critical materials and give in a general way what has been done to try to reduce this usage.

SUBSTITUTION FOR CRITICAL MATERIALS IN JET ENGINES

I cover the jet engines first. Two means have been adopted for trying to reduce the very high usage of critical materials in jet engines. One of them is the Air Force program of goals per thousand pounds thrust.

They have indicated in every contract for the procurement of jet engines that the manufacturer should meet goals of not more than 35

would find out why they were not ordering what they said they were going to.

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pounds of nickel per thousand pounds of thrust, 40 pounds of chromium, I think it is a quarter pound of cobalt, and so on down through the list of the critical materials.

These have been fairly effective. We had some charts made up the other day which indicated for certain selected engines which had been in this program for 3 or 4 years. These charts showed how much critical materials these engines used at the beginning of this program and how much they use today, with no reduction in performance at all.

In fact, in some cases there was an improvement in performance. Improvement in the power of the engine. They are using substantially less of most of these critical materials today than they were 4 years ago.

Senator MALONE. Do you mean they are substituting other metals?

Mr. GARRETT. Yes, that is what it is.

For instance, instead of using a solid sheet of stainless steel, they may use ordinary carbon steel that has been dipped into aluminum to give it a heat-resistant coating, or instead of using a high-alloy steel somewhere, they may use another alloy that has less of the critical material, but which is still strong enough to do the job.

In other words, the early engines tend to be overdesigned. This is true of any piece of military equipment. When the first model is designed, you don't know for sure just how strong it has to be.

This is determined by testing. And you overdesign it at first. Then you start cutting down here and there.

The other approach that has been taken is to make contracts with 2 or 3 of the engine companies to specifically design an engine with certain characteristics with the least possible critical materials in it, not with the idea that this engine will go into production immediately and be widely used, but just with the objective of finding out what is the farthest we can go if we have to in cutting down on critical materials.

Two or three very successful engines from which we have learned a lot have been designed in that way.

Then I mention here the use of critical materials in guns. This is over on page 5. Guns is another field.

REDUCTION OF CRITICAL MATERIALS IN ORDNANCE

I might say, for a moment, to give a little background here, that there are two general ways in which military equipment is bought. Some items are bought on a specific design. That is, say, the Ordnance Corps of the Army will design a piece of ordnance equipment and they will make the manufacturing drawings down to the last detail.

Then they send those drawings out and ask for bids on them. On those things, the contractor who is building the thing is not responsible for the design, and the Army can put in whatever materials they think are adequate and they can make them lean as they think they will do the job.

Other items, and this includes airplanes, jet engines, guns, armor, and a number of other things, are procured on what are called performance specifications.

Here the Army, the Air Force, or the Navy, as the case may be, issues the performance characteristic that they desire to contractors and then ask the contractors to design an article to meet those characteristics.

In this case, the department does not control the materials that go into those items and they have to use, you might say, moral pressures on the contractors to cut down on the use of critical materials.

Guns, as I said, are in that category. They are generally not, with the exception of small arms, but the larger artillery weapons are, in general, purchased on procurement specifications and there is a considerable latitude on the part of the contractors on what materials will go into them.

But due to the constant pressure that is brought on them by the Ordnance Corps, they use nickel, chromium, and molybdenum, which are the chief materials that go into gun steels as alloy elements, have been very substantially reduced since the end of World War II.

The same thing is true of armor.

It is quite interesting that there are, I think, five major producers of armor, and the compositions that they furnish are quite different, because each has their own composition and some of them are considerably leaner on critical materials than others.

But overall there has been a considerable saving of nickel, chromium, molybdenum, vanadium, and so on in the armor field.

CRITICAL MATERIALS IN ELECTRONICS

Then I mention the electronics field. I mention five materials that are critical, that are widely used in that field.

Mica, quartz, crystals, selenium, block talc, and germanium.

In the case of mica and quartz crystals, we have learned how to make synthetic materials that will in most cases, or many cases, at least, do the job that formerly required natural mica and natural quartz.

Senator MALONE. Are you familiar with the work of the Mica-Flex Corp.?

Our attention was directed to it and we examined some of the material, merely to verify some of the testimony. Does it live up to its general reputation?

Mr. GARRETT. I think so. Snythetic mica is still under valuation by the Signal Corps and others, and it takes a good, long time to fully evaluate these synthetics. It takes perhaps 2 or 3 years of service testing to get complete assurance.

Senator MALONE. Do you think there is ever a possibility that it will do the work?

Mr. GARRETT. It certainly will in many applications.

Now, of course, there are all kinds and grades of mica.

Senator MALONE. That will cut down the amount needed in any case?

Mr. GARRETT. That is right.

Senator MALONE. Do you know what the annual use of mica now amounts to?

Mr. GARRETT. I don't have the figures in my head.

Senator MALONE. If you could give us an estimate of the amount used in national defense and the amount used annually. Also tell us what you know about synthetic mica now, how much it will cut the national defense needs of regular mica, or how much dependence could now be placed on synthetic mica.

Mr. GARRETT. I will get that information and supply it.

Senator MALONE. Now, with the quartz crystals, what is the situation there?

Mr. GARRETT. We can grow quartz crystals which, as far as I know, are in most applications suitable for the natural quartz.

In addition to that, there is some research and development going on on developing electronic circuits which will have other means of controlling frequency than quartz, which, again, will reduce our dependence on quartz.

Senator MALONE. Will you do the same thing on that for us, actual dependence by national defense on quartz crystals?

Mr. GARRETT. I will do that, sir.

Senator MALONE. That will be the important fields, because we assume in peacetime you can secure quartz crystals wherever necessary, but in wartime you could not.

Do that for each one of these materials, if you will.

Mr. GARRETT. On selenium, block talc, and germanium, the situation is somewhat different from mica and quartz crystals. In those cases there are other ways of doing the thing, and there is a great difference of opinion on some of these things as to whether one way or another way is the best way of doing it.

Because of these differing opinions, it is difficult to give as clear cut a picture as we might in mica and quartz.

Senator MALONE. Would not the main thing be, can it be done in another way? Whether it is advisable or not, if it can be done as efficiently, then there is no choice in wartime unless it is available in this hemisphere.

Mr. GARRETT. I think the difficulty on selenium is that selenium rectifiers are pretty new, and they are very widely used in television, for example.

There are other kinds of rectifiers that definitely can be used, germanium, silicon, titanium, and so on, but these are even newer than selenium. They are in the research and development stage.

So while we think that these other things are going to come along so that they can be substituted for selenium, you cannot tell for sure on a new development until it has been fully tested.

That is the difficulty we are in now, that they are not fully tested.

Senator MALONE. Give us the status of the tests.

Mr. GARRETT. Yes.

Senator MALONE. And also you might outline the use of each one of these materials in national defense.

Mr. GARRETT. All right, sir.

I have a pretty good picture on block talc that I can give you right now.

Senator MALONE. Very good.

Mr. GARRETT. We have given some real study to the block-talc situation. The picture seems to be on block talc that there is one company that uses a very high percentage of all the talc that is used, and there are a few other companies that use substantial amounts.

But the great bulk of the electronics industry does not use any. There are, then, two opinions on block talc, and it is the hardest thing in the world to tie down, whether these few people that say they need it and do use it, whether they really do need it, or could go to substitute materials.

We feel in the research and development end of the business that there are fully adequate synthetic substitutes for block talc, and we would say that you don't need to stockpile any block talc.

But there are these few companies that say "We need it," and because of that, those who are responsible for the stockpile have not been willing to stop buying block talc, for the stockpile.

This is a question which we in research and development cannot resolve. I don't know who can resolve it.

Senator MALONE. At least, in your opinion, the heat is off.

Mr. GARRETT. It is our opinion that this is not a serious situation.

Senator MALONE. And if war was declared tomorrow, you can go ahead and do everything you are doing now.

Mr. GARRETT. That is right.

Senator MALONE. I think that is all that is necessary.

Naturally, in peacetime they can use whatever they choose to use, if the economics work out.

Mr. GARRETT. Yes; but the difficulty is that these few companies say that they can't get along without it in wartime. We think they can, but they say they can't.

So we are still stockpiling the stuff.

Senator MALONE. The stockpile would be entirely adequate in any case; is that right?

Mr. GARRETT. It is our opinion that it would, although it is still being bought.

A good many of our advisers say we are wasting money by buying block talc for the stockpile.

Senator MALONE. If we could reduce all of those questions, to that basis of argument, this committee would dissolve. We will let you argue it out.

Mr. GARRETT. I put in a brief paragraph here on industrial diamonds which is a very interesting situation, I think.

POSSIBILITY OF SUBSTITUTIONS FOR INDUSTRIAL DIAMONDS

Senator MALONE. Go ahead with industrial diamonds. We are very interested in that.

Mr. GARRETT. Yes, sir. I noticed in your report, or I guess it was in the Bureau of Mines volume of testimony, that industrial diamonds was indicated as being rather unique as the only one of the strategic and critical materials on which we were wholly dependent, or, at least, very largely dependent on sources outside of the Western Hemisphere.

Senator MALONE. There was some very interesting testimony by Mr. Oliver Ralston, who is one of the most experienced and efficient men in the Bureau, and boiled down we have said, on page 79 of the report, which is a digest of all the testimony:

> Use can be reduced by half through substitutes.

In that volume, Mr. Ralston went into considerable detail as to how it was done.

Mr. GARRETT. We had a study made of the new ways of grinding things.

Senator MALONE. Of course. That is good. I was just going to say that industrial diamonds do not pose a transportation problem. Air transportation would be very easily arranged if they were available any place.

Many believe that if a little attention is given certain areas in Brazil and South America, that you would develop a supply sufficient for wartime uses.

Go ahead.

Mr. GARRETT. Because of our dependence on foreign sources of industrial diamonds, and also because it would be desirable to be able to produce in any desired quantity this hardest of all known material, it has always been a great temptation to do research on trying to find out how to synthesize diamonds.

Some 5 years ago, or nearly 6, now, a detailed study was made by the old Research and Development Board of the possibility of synthesizing diamonds. A highly expert panel of scientists was assembled, people who have worked in this general field of high pressure and high temperature research.

They came out with a report which indicated that in their opinion it would be feasible to synthesize diamonds. They estimated that it would require an effort of something in the neighborhood of $10 million and it would take 5 years to do it.

This was all pre-Korea, and money for research in the Department of Defense was very scarce in pre-Korea days.

This was a large program in those times and it was not undertaken.

We again considered the possibility of going into such a program about a year ago, but in the meantime, in these intervening years, a great deal of development work has been done on these new substitute methods on electroarc grinding and other kinds of electrolighting grinding, and development of silicon carbide belts and wheels, and 1 or 2 others.

We had a study made by the Materials Advisory Board, I guess it must be nearly 2 years ago now, to advise us to just what extent these new methods could wholly substitute for diamonds. Their report indicates that it would be possible to do every tool sharpening job that diamonds can do with these new methods, but the only question that they couldn't resolve was how costly it would be to do so.

It boils down largely to a matter of what would this do to your productive capacity, whether this would slow you down too much.

This is a question that has not really been wholly answered because it seems as though we have to get more experience in actual use in this equipment to determine what it is going to cost to grind tools.

Senator MALONE. What was the organization you put the question up to?

Mr. GARRETT. The same board, the Materials Advisory Board.

Senator MALONE. Who headed up that particular study? Will you give us that information?

Mr. GARRETT. I will be glad to get that.

(See letter and enclosures, p. 286.)

Senator MALONE. This is very important. If substitute methods can be designed, or have been designed to do the work of industrial diamonds, any kind of blackmail from other nations is blocked.

You know, India stopped the shipment of monozite sands in peacetime, to the United States. We did not have to wait for a war.

But cost is not the controlling factor in wartime. If we can do this, going without industrial diamonds, or use a substitute for industrial diamonds and it would not slow down production too much, we would not really have to worry about it.

I would be interested in following that through further.

Mr. GARRETT. Well, as I say, they did indicate that you can physically do any job; you can sharpen any kind of tool, with any one or another of these substitute methods, but I think it is largely a case of—well, as you say, that it really boils down, I think, to a case of cost, of how much equipment you have to put in to do the job.

But to some extent, it takes manpower to operate the equipment. If you need highly skilled toolroom labor and if you need 3 or 4 times as many of these people to sharpen tools by these methods as with the diamond wheels, that would be a factor in wartime production.

Senator MALONE. That would be a factor, but could we not pin it down a little better as to what is involved in it?

Mr. GARRETT. We may be able to now. Two years ago they said there was not enough experience, but we may be able to do it now.

Senator MALONE. I would be very interested in your furnishing other information as you can to the committee.

On this matter of germanium, tell us a little more about that product.

POTENTIALITIES OF GERMANIUM RECTIFIERS

Mr. GARRETT. This is a highly specialized electronic field, and I must say that I don't know all the technical factors involved.

I do know that theoretically you can make a germanium rectifier so small that the size of the rectifier is no larger than the copper conductor that is needed to carry the power to the rectifier.

The big problem is cooling. It overheats because it is so small.

You have to have all kinds of water-cooling devices, if you are using it for power purposes, to keep it cool. This does develop interesting possibilities.

You know, for many purposes a direct-current motor is better than alternating current. The speed is more readily controllable and so forth.

These new rectifiers open the possibility that you may be able to build a rectifier into the end belt of the motor and bring the power into the motor, and run it as a direct-current motor.

So there are all of those possibilities. The main use at present is in transistors.

There, as I understand it, the problem has been unreliability. The moisture level of the atmosphere affects the performance characteristics.

Also, it has very definite temperature limitations. Electronic equipment, of course, and particularly military equipment which you try to pack into a small space, runs very hot, and there is a question as to whether the germanium will stand the heat for military applications.

So a good deal of effort is going out on other kinds—or other ways of doing the same job. They are working on silicon and on titanium, among other things.

All of these things are in a state of development, and there really are no answers today.

Senator MALONE. Would you feel that you might get us further information from the electronics industry people actually in the industry?

Mr. GARRETT. Yes, I can get more detail.

Senator MALONE. Furnish us any detail that you can. We would appreciate it.

Now, you may go ahead.

Mr. GARRETT. Then on page 8 of this report, I have finished up the general introduction. You will notice I have listed certain materials. These are the materials which the conservation people in the Department of Defense feel are most worthy, most needing conservation, and they are listed in the order of expected scarcity.

In other words, nickel is expected to be the most scarce material, and molybdenum next, and so on through abaca and tantalum.

Senator MALONE. You know we are the chief producers of molybdenum in the world?

Mr. GARRETT. Yes.

Senator MALONE. As a matter of fact, molybdenum, tungsten, titanium, and certain other minerals are interchangeable to a certain extent in certain uses. Nickel—are you familiar with the work going on in Cuba?

Mr. GARRETT. Yes, in general way I am, and I understand that the capacity to produce nickel is something like 50 percent greater today than it was at the end of World War II, because of such things as the Cuban development.

Senator MALONE. And it has possibilities of increasing materially as they whip this complex ore that contains nickel and chromium together, I understand.

Mr. GARRETT. Nickel and cobalt.

Senator MALONE. In any case, we expect to find out more about that.

NEED TO ESTABLISH HEALTHY INDUSTRIAL CLIMATE FOR STRATEGIC AND CRITICAL MATERIALS

Mr. GARRETT. There is one thing I would like to suggest at this point, speaking of nickel as a good example, and I think molybdenum might be another, and that is that it would seem that the best way of overcoming these shortages of these highly critical materials would be to simply establish conditions such that more of them would be produced, because I think the nickel is in the ground. I think we can get more nickel. I think it is just a case of paying enough to dig it out.

Senator MALONE. You are talking about industrial climate for business in these fields?

Mr. GARRETT. That is right.

Senator MALONE. That is what I talk about all the time, even in my sleep.

For, a chief criticism that I always have for the Government departments is that these men try to establish rules and regulations under which private industry, just simply cannot operate.

If there is a principle adopted, on the other hand, like making up the difference in the wages, taxes, and the cost of doing business that is automatic with the Tariff Commission, it should increase individual effort to discover the needed metals.

In other words, we create conditions that bring about the thing we fear, and that is the shortage of the material.

We had a Secretary of the Interior who had an idea that through the Department of the Interior they could conduct better investigations all over the United States than the prospectors. All they had to do was to appropriate money and put enough men on the job just out of college.

Of course, they did just about run out of material, too. Then they tried for many years to do away with the depletion allowance in petroleum, with speeches on the Senate floor and on the House floor that this was a terrible thing.

Right off, there was a dry hole. They were always out of oil; they were always out of petroleum, or just about out of it; they would have to save these greater reserves.

Some of us said if you will just let it alone and establish an industrial climate so that they are pretty sure it would be let alone, a depletion allowance, it would be running out of your ears in a little while. That is what it is now doing.

We also said many of these other materials would be the same way. At least, production would be increased materially.

So the Senate Finance Committee this time recommended to the Senate, to Congress, and it was adopted, to raise the depletion allowance on 31 minerals from 15 to 20 percent, which was a great incentive.

But the difficulty now is the competition from the low-wage countries, and that is in your hair all the time.

So if we could just allow the 1934 Trade Agreements Act to expire at midnight on June 12, 1955, the responsibility would go to the Tariff Commission and that would be a great incentive to business.

Then, if you had to have more protection, and this is a difference in the effective wages and the taxes and the cost of doing business between this Nation and the chief competitive nations in that particular production, there is the place for your subsidy.

Congress could then take it up and it doesn't take long. You are operating tungsten now, right on top of the peak of supplies of this Nation, now, by virtue of my bill. They pay so much a year for tungsten. They pay so much for manganese.

It guarantees a price for chromium and some other metals for a certain period. But you can only invest money that will be returned to you before that period runs out, because you do not know what Congress will do and there is no policy, no principle.

If you had the principle established, you would not need the bill.

We might take the materials that are only on the critical list and just have the principle apply to them first, to see what it does.

Do you think the National Defense Administration would seriously study a problem of that kind, just to apply to critical materials that they pronounce are critical?

Mr. GARRETT. Well, I would think so. I think there is a tendency on the part of the Government people who are figuring supplies against requirements to think of the supply end of it as being relatively fixed; that there is only so much material available.

Senator MALONE. Of course, there is nothing more erroneous or dangerous to this country.

Mr. GARRETT. That is right.

Senator MALONE. You understand that; don't you?

Mr. GARRETT. Yes, sir; I think it all depends on the price. I think if you raise the price and maybe not very much on a material, you may open up lots and lots of things that are ordinarily considered plain rock and they immediately become ore if the price is high enough.

Senator MALONE. You are ahead of me. I wish we had a few more with that theory in Government.

Mr. GARRETT. I think that nearly covers the things I had in my statement here. The rest of it is a little more detailed, perhaps, on a few of these materials.

RESEARCH COULD HELP ELIMINATE NEED FOR A STOCKPILE ON SOME MATERIALS

There is one other thing I wanted to mention in regard to the overall objectives of our research and development program on materials. Necessarily, the place the departments spend their money on research are directed toward achieving the improved military equipment that the departments are always looking for.

I have always felt that there is a phase that is being overlooked; not exactly overlooked, but no provision made for it.

A good many of these materials that are kept in the stockpile are quite costly. I think the total stockpile is somewhere in the neighborhood of $6 billion, or a little over, and just the interest on that costs a lot of money each year.

Senator MALONE. We give ten billion a year each year to Europe. I don't think we are going to worry about that until we get our feet on the ground on some other things.

Mr. GARRETT. The thing I was getting at is that there are some of those materials, and I think rubber might be an example, where, I think, if money were spent on research we could almost eliminate a need for stockpile, and the amount we spent on research would be less than the annual amount of maintaining the stockpile.

Senator MALONE. Have you made any estimate of what you would need for research and the time element involved—the annual need, listing these materials one by one in some overall amount?

Mr. GARRETT. We have only done that on rubber. The reason I mentioned rubber was we are just now completing a study on rubber. We think that through the expenditure of $20 million over 5 years we could very likely eliminate the need.

Senator MALONE. That would be $4 million a year.

Mr. GARRETT. For 5 years.

That may eliminate the need.

Senator MALONE. No Senator for 20 years has ever stopped a minute to consider $20 million. Unless you want more than that, they probably would not even appropriate it for you.

No. 11 of our 12 recommendations, beginning on page 3 of report No. 1627, recommends appropriations of $50 million and usually to establish and operate a comprehensive 5-year program of laboratory, pilot plant and exploratory research, in improving methods and beneficiations of critical materials and the study of substitutes including synthetics and replacements.

I just had in mind, people who estimate like Harry Dexter White, who took advantage of what is generally misunderstood as reserves, the public not understanding it at all, and put a false meaning on reserves, and nailed it down.

When an engineer says to a mineowner, "You have 200,000 tons of reserves", he means it will pay to mine as of now.

But with economic changing conditions, and while you are mining this 200,000 tons and further exploring, he knows, and if you ask him he will tell you, that you will probably discover more.

Using the profits from this, then, you mine. No mine that I know anything about ever has more than 2 years or 2½ years actual reserves because they can't afford to save it while they are piling it up underground. They start to mine when they know they have enough to pay out the machinery and the expenses of going in and then they continue the research and exploration.

A mine that had 100,000 tons 10 years ago may have 150,000, and nobody is worried. Eventually maybe they will run out, but meantime they found another one.

We know that when any organization slows down its laboratory work, or its exploratory work, probably in 5 years they are out of business.

If they keep their research going, it changes every day.

What we need in Government today is people who understand these things. I don't know whether you need $50 million for all of this, or $100 million.

We nearly made it $100 million. But I said let's put it at $50 million, and if somebody shows us some more evidence, that can always be raised.

What we meant here was to give you what you need to do the job, but you had to break the ice. You won't have any trouble over here if you will just tell them what you want it for. It is not only for rubber, but it is more for many other things.

Mr. GARRETT. I think we can get over this difficulty on rubber, particularly. But there is one difficulty, and that is that if the objective of research would be solely to save the Government money on what they are carrying in the stockpile, the Department of Defense probably wouldn't take very many millions out of their money to spend in that field.

What we need here is some kind of a policy direction to somebody. I think the Bureau of Mines could do part of this work and the Department of Defense could do part of it, but there needs to be some kind of a policy statement that this should be done, that it is an objective of national policy to do research in order to save money on carrying materials in the stockpile.

Senator MALONE. That would be one facet of the objective, to save the money, and you could save a considerable amount.

The other facet of it, of course, is to become independent.

You have covered here how many materials? Is it these materials that you name on page 8?

Mr. GARRETT. These and some others. We covered first these that are listed here.

Senator MALONE. Name the ones in the order of their importance as you have covered them in your report.

Mr. GARRETT. Nickel, molybdenum, abaca, tantalum, selenium, asbestos, copper, chromium, cobalt, waterfowl feathers and down, columbium. Asbestos again. This first entering of asbestos was amosite and then we cover the chrysotile asbestos.

Industrial diamonds, mica, aluminum, silicon, rubber, quartz crystal wool, cadmium, and finally titanium.

Senator MALONE. What is your size-up of the situation, just briefly in the self-sufficiency of the Western Hemisphere considering replacements and substitutes if you are allowed ample, we will say, amounts of money for research, and in reaching that point where your stockpile plus your going capacities in the Western Hemisphere would equal what you need?

Mr. GARRETT. Well, I read the testimony of the Bureau of Mines on this subject, and they, of course, have the experts in this area. I am not. I am really not in a position to have an opinion except as it is formed by such testimony as that given by the Bureau of Mines.

Senator MALONE. I understand that, and I respect you for it. The chairman is that way. The longer you spend in the business, the greater respect you have for a man who spends his life in a certain business. You do not in a day or two learn more than he knows, even if you are trained in the business, as a very few are.

Mr. GARRETT. There is one statement Dr. Jeffries made on 1 or 2 occasions that I think is very pertinent to this particular study. He points out that, in the field of metals, at least, there is not any metal that, if you increase the supply of it, will not relieve or tend to relieve shortages on other metals, that there is always such a degree of interrelationship among all the metals and all the alloying elements that go into metals, that by getting more of one thing you can help relieve shortages of another.

So to some extent the thing to do in going about relieving these shortages is to look for the places that you can get more metal most economically and expand those areas.

Senator MALONE. And then explore the fields where that would act as a substitute for the scarcer metals.

Mr. GARRETT. Yes.

Senator MALONE. We touched that field in each of the metals and the supporting data supporting the 12 recommendations. For example, whenever substitutes were needed, we named other metals or other materials that were, to some extent, substitutes.

What Dr. Jefferies says is absolutely true. It is a shame that men like Dr. Jefferies, if he has a turn of mind of that kind, has not, maybe, written a comprehensive work on that sort of thing. We would be very happy to get it. Where does he live?

Mr. GARRETT. In Pittsfield, Mass.

Senator MALONE. Perhaps sometime we could get him down before the committee and you could bring him with you.

This report will be accepted as an exhibit, exhibit No. 1 of your testimony.

Do you have any further statement?

Mr. GARRETT. No, sir; I think that is everything I wanted to say.

Senator MALONE. I hope you will convey to your superior, Mr. Quarles—he is your superior?

Mr. GARRETT. Yes, sir.

TITANIUM—PROGRESS ON EXTRUSIONS

Senator MALONE. What we have told you, and tell him that we would like to discuss this entire matter with him sometime.

Can you tell me what emphasis, if any, is being put on this fabrication roadblock now?

Mr. GARRETT. Our steering group is particularly looking at extrusions at the moment. We feel this is an area that offers great promise and one that has not had very much work done up until now.

We have, as I think you know, a proposal from Harvey Machine. We were getting proposals from a number. In fact, we are going to contact everybody that we feel has the capability in this area and try to get all of those interested working on it, finding out how to make good titanium extrusions.

Senator MALONE. How would you do that job? How would you put the responsibility, say, on the Harvey Machine Tool Co.? Is that by a contract?

Mr. GARRETT. Yes. The Air Force would make a contract with them.

Senator MALONE. Would you only make a contract with one organization?

Mr. GARRETT. No, we plan to make a contract with several.

What we want to do is find out all of those who would be interested and then as many of those as are willing to go ahead on a more or less equal basis.

I don't think we could give 1 company a lot more support than we would have to give 2 or 3 others.

Senator MALONE. According to their size and experience and organization?

Mr. GARRETT. Yes. I would expect to give several of them these contracts to do experimental work on extrusions at the same time.

Senator MALONE. You would not confine it to extrusions, would you?

Mr. GARRETT. The extrusions are the things that to us seem to need the most work. That is, we think they are behind other methods of fabrication.

Senator MALONE. How about the alloys themselves?

Mr. GARRETT. That is another field. We are, of course, already supporting alloy development, but one of the things that our steering group is putting together right now is an indication of what further alloys need to be developed. That is, what further properties do we need that we don't have from our present alloys.

When we get that finished, which should not be very many more weeks now, we will go to all the companies that are developing alloys, and we will try to find out whether they are already working in that field, and whether they need Government support to develop these improved alloys.

Senator MALONE. Will you let them know that you are ready to give them some financial assistance, making the results available to you, and the importance of it, the extreme importance of it?

Mr. GARRETT. Yes, sir.

This is being given far greater prominence than any other materials problem in our thinking, and in our work.

There is another approach we are taking to this titanium business. We feel, as I mentioned before, that there are two things holding up the wide-scale use. One is what you mentioned, the nonavailability of high tonnages, before a company can go into it.

The other is the lack of widespread experience in using, not in fabricating titanium, but in what titanium will do in service.

To overcome that, we are approaching the thing from this point of view: We are going to go to all the big airplane companies and all the big engine companies and see if we can make contracts with them for the experimental application of titanium in every conceivable place where it might be used, have a number of items built and then test them thoroughly to destruction so we will quickly get the service experience that we need.

Senator MALONE. It has been brought to my attention, that we were informed that an all-titanium plane is being manufactured by some organization, an experimental plane. Do you know anything about that?

Mr. GARRETT. I don't know about that in detail. Some years ago, and this may be the one you are referring to, a contract was let with Republic Aviation to design an all-titanium airplane. I think this contract was a little ahead of the times.

I believe it is almost 5 years ago that the contract was made. As far as I know, the thing kind of petered out. I was not directly associated with titanium at that time, and I don't know exactly what happened here.

But I haven't heard anything of this contract for about 3 years now, and I just think that it was somehow out of step with conditions. I don't think they are going forward with that.

Senator MALONE. They did not at that time have the necessary alloys.

Mr. GARRETT. That is right.

USE OF TITANIUM IN FIREARMS

Senator MALONE. Are they using titanium in firearms at all?

Mr. GARRETT. A little bit. At the present time there is just one production application, a 20-millimeter machinegun. It has a gas piston that actuates the automatic mechanism which is made out of titanium.

Senator MALONE. Does it stand the firepower like steel, in the barrel?

Mr. GARRETT. There are no barrels, except experimental, made of titanium. There are experimental barrels of titanium and I think they work out very well.

But the thing the Army is faced with there is when they buy something, like a machinegun, they buy it by the thousands or even the hundreds of thousands, and the cost at present is an obstacle.

Senator MALONE. And the amount of titanium available, I suppose?

Mr. GARRETT. I think if they wanted to make these things of titanium, it would not take too long to build up production capacity to make them. But they say—this is nothing I say, but Army Ordnance says—that somewhere around $3, and possibly up to $5 a pound is about as much as they can spend for mass use of titanium, tonnage use of it.

Senator MALONE. If you could make a machinegun that one man could carry very handily, the weight saving there would put the cost in the background; would it not?

Mr. GARRETT. You can't always think that. At least, the Army people feel that if they put titanium into their things in a big way, they would not get larger appropriations overall, necessarily, and, therefore, they could only buy fewer of these things.

Senator MALONE. Have they ever asked for it? Let me say something to you: What we are talking about is the protection of the

United States of America. One of the favorite sayings for 10 years is a $75 billion budget was 85 percent national defense, prior or future.

It is a crazy thing when you break it down. Nearly $20 billion was spent abroad, is being spent abroad, annually, for our protection.

In the opinion of some, very little of it is being spent in the right spots. And they are talking about costs of a material that would hasten the protection of this country here. It does not make sense.

Mr. GARRETT. On this question of price, I have heard nothing to back it up, but it will not be too long, and certainly within the foreseeable future, that the price will be down to that level.

Senator MALONE. When you start using it?

Mr. GARRETT. Yes.

FORGING OF TITANIUM

Senator MALONE. Now, what about forging of this material? We talk about extrusions, forging of the metal, the shapes, the various kinds. Are we following through on that?

Mr. GARRETT. Yes; a study has just been completed by the Cornell Laboratory up in Buffalo on the troubles that are being encountered in the aircraft industry on the use of titanium. One of the things that they pinpointed was this trouble with forgings.

The trouble there seems to be in the fatigue properties of the forges. That is some people have had the experience that when they get it into a complicated shape forging, the fatigue properties of the material are not as good as in an ordinary test bar.

The odd thing about this is that other companies have not run into this; in other words, it is not uniform. Some have and some haven't.

We are pretty sure from that that it is not an inherent shortcoming of the material, but there is something wrong, perhaps, with the way the forgings are being made, or the way they are being tested, or something.

Senator MALONE. Is there anybody, even in your organization, that thinks any of these problems cannot be whipped if you get at them?

Mr. GARRETT. Certainly my organization does not. I can't speak for others.

Senator MALONE. You think they can be whipped?

Mr. GARRETT. I am confident they will be.

Senator MALONE. And the time element is not great, if you have the money to spend on them and get these competent organizations working on them.

Mr. GARRETT. That is right.

I was going to lead up to another step in our new organization that we are going into. We have felt that to overcome this kind of problem, this thing on forgings and other similar problems, what we need is a body of technically competent people who can go around to the places that are having this trouble, who will know all there is to know about titanium, not what others experiences have been, and be able to help these people overcome their difficulties.

To get this sort of thing, we are setting up a contract, a rather large one. It is going to be approaching a million dollars a year, with the Battelle Memorial Institute in Columbus. We feel they have more knowledge and more experience with the metallurgical properties of titanium than any other body in the country.

Senator MALONE. Is that the only one you are going to charge with that responsibility?

Mr. GARRETT. With the responsibility, yes. They will do the work, but they will do it under the general direction of our steering group.

Senator MALONE. Do you not have other companies working on it? What is the problem you are giving them?

Mr. GARRETT. We call it a titanium metallurgical laboratory. We drew the parallel with the aluminum business in the early days.

In the early days, the Aluminum Co. had a monopoly of the aluminum business, and they promoted aluminum.

The way they did it was to give very good customer service. Whenever anybody had trouble with aluminum, they had someone on the spot to find out what was wrong and to help them. This is what we think is needed in titanium today.

Senator MALONE. It may be that you would not need so much customer service until you get some material for them to use.

Mr. GARRETT. We think this is one reason that they are slow in using the material. We think this will be one step to help out.

Senator MALONE. Would it interest you to know that we had a witness here one time who had a very comprehensive set of experiments with each part of a jet plane plus the tests that had been run on each part, and he had an idea that you would not start making an all-titanium engine or put titanium in all the parts that you know it ought to be in until you had the titanium.

But as they were assured they could get the titanium steadily from their own, they would add a part and that part would go in to stay. And as they got more, the next one would go in to stay.

They have already run the experiments and have been very satisfactory.

Do you know anything about a company of that kind?

Mr. GARRETT. I am sure several companies are in that position. I wholly agree with you. I am not disagreeing with you that what we need is a large availability of titanium before these people will put it into their designs.

Senator MALONE. Then I come right back to the only question there is: Who is responsible for ordering it?

Mr. GARRETT. That depends on what we mean by ordering.

Senator MALONE. Sponge is the first thing they have to have under your present setup, is it not?

Mr. GARRETT. The individual companies are the ones that order it for their uses.

Senator MALONE. No. Why do you ration it?

Mr. GARRETT. The only thing the Government——

Senator MALONE. Why do you have it set up so that only the national defense can get it unless by your permission? You do have that, do you not?

Mr. GARRETT. This is something completely out of the Defense Department, and I don't feel I ought to get into it.

Senator MALONE. Who ought to?

Mr. GARRETT. Anything I might say might be interpreted as criticizing the other departments.

Senator MALONE. I hope you do. I am going to, if I do not get any information pretty soon.

Mr. GARRETT. The rationing is set up by the Business and Defense Services Administration, and I know very little——

Senator MALONE. Who is that?

Mr. GARRETT. The Department of Commerce.

I know very little about why they are in this picture and what they do.

Senator MALONE. Now, we have to get another department?

Mr. GARRETT. That is right.

Senator MALONE. Who does it over there? Who is the head of it?

Mr. GARRETT. The person in charge of titanium specifically is a Mr. Cullen.

Senator MALONE. What is his first name and what is his position?

Mr. GARRETT. Herbert L. Cullen, analyst for Business and Defense Services.

Senator MALONE. It may be that there are 5 or 6 other departments in this thing. What does he do? Does he ration it?

Mr. GARRETT. I think he does.

Senator MALONE. You think he does. Do you have the first call on it in national defense?

Mr. GARRETT. Yes, sir.

Senator MALONE. Who has the second call on it?

Mr. GARRETT. My understanding is that the present order, or whatever it is that these people issued, says that up to 10 percent of titanium production will be set side for civilian applications, and 80 percent will go to the military.

But as I understand what has actually occurred today is that less than 10 percent has been called for by civilian applications so that the whole 10 percent has not been used.

Senator MALONE. Do you have any idea why that is true?

Mr. GARRETT. Why less than 10 percent?

Senator MALONE. Yes. Why less than 10 percent has been called for by civilian industries.

Mr. GARRETT. I think it is all the reasons that it has not gone in to military equipment as fast as we had hoped it would.

I believe all of those reasons apply also to the civilian industry.

Senator MALONE. Do you mean because of the alloys not being satisfactory and various things?

Mr. GARRETT. That initially.

Today I think the alloys are satisfactory, but I think today the things that are holding it back are three things: One, the lack of availability of the metal; two, the lack of service experience with it; three, the price. I think those are the three things.

Senator MALONE. Do you know that price does not at all retard the use in civilian industry or anyplace else? Do you know the testimony before this committee was that on the civilian planes used in service of the public, commercial planes, it was testified that they would pay $80 a pound for it and it would pay out in the life of the material because of the increased payload?

Mr. GARRETT. Yes.

Senator MALONE. Well, what are we talking about the price, then, retarding it? They cannot get it in amounts so that they dare start to use it.

Mr. GARRETT. I want to clarify what I said about price.

Senator MALONE. You know it is not true.

Mr. GARRETT. I think in certain applications, in things that fly, you can justify today's price. But I think in a lot of civilian applications, for example, in valves and plumbing equipment——

Senator MALONE. What do you base that on, your personal knowledge or what you heard?

Mr. GARRETT. Well, everybody's personal knowledge is what they hear, if you take it back far enough.

Senator MALONE. I will give you some new information and you can find it in those 11 volumes, or I will have George find it for you. The Monsanto Chemical Co. representative sat here and testified that they could use a tremendous amount and wanted it at the present price. They were not questioning the price, did not ask about the price, because they wanted the material because it is resistant to certain chemicals. Very few chemicals attack it, apparently.

The milk industry representatives sat here and testified they wanted a tremendous tonnage of it but cannot get it at the present price. Where do we get this idea that there is no demand?

Mr. GARRETT. I would like to say this about those statements. Certainly nothing the Government is doing is preventing these people from getting titanium.

Senator MALONE. No, certainly not, except that it is rationed. That is all. Then we have to go through Mr. Cullen's department to get an order to make more titanium or to let more contracts. Is he called in on that sort of a thing?

Mr. GARRETT. Apparently he is. I would like to say this here: That I personally believe that titanium should not be rationed.

Senator MALONE. Is it?

Mr. GARRETT. If it is rationed——

Senator MALONE. Do not tell me "if it is"; is it?

Mr. GARRETT. I do not know, to tell you the truth.

Senator MALONE. Can you find out?

Mr. GARRETT. I will try to find out.

Senator MALONE. How am I going to find out if you do not know? You are running the business.

Mr. GARRETT. It is not rationed by the Department of Defense. This is completely out of our hands.

Senator MALONE. I am not asking you that; I am asking if the Government rationed it.

Would you mind doing a little job for me? Would you trace this thing through for me and put every Government department in it that touches this thing from top to bottom, from when you determine the need for it and you order it made or contracts are let to make it? I believe that would be a project.

Mr. GARRETT. I will be glad to do that. In other words, get all of the people in the Department of Commerce, the GSA, the ODM and the Air Force who are concerned with it?

Senator MALONE. Yes. You might even go further than that, until it gets into an airplane, fabricated, whether it is extrusions or forgings, or whatever it is; the allocation and the rationing, and the whole thing.

Mr. GARRETT. I could make one observation here on titanium that I have thought of several times. We have mentioned that on expanding these materials we ought to make conditions favorable so that

industry can do it and so that the Government does not have to plan everything. I think one of the reasons that we are in a lot of trouble on titanium is because it seems to be more or less necessary at this stage for the Government to take a pretty big hand in the planning. I think any time the Government plans something, even though they are doing the best job they can, they cannot do as good a job as you can under normal conditions.

Senator MALONE. What is the relationship between the Wright Airfield and your Defense Administration?

Mr. GARRETT. The buying for the Air Force is done from Wright Field, the Air Material Command. They let the contracts to buy airplanes and engines.

Senator MALONE. Do they have anything to do with the determination of whether you are going to use this titanium or not?

Mr. GARRETT. The actual determination is made by the individual companies who are making airplanes and engines. But the Wright Field people ask them what they are going to use. They assemble these requirements from them.

Senator MALONE. Now we are back at the other stumbling block. According to the plane manufacturers and engine manufacturers, they want 150,000 tons. If you ask them how much they want to buy for what they already have off the drafting board and what you have ordered, that might be an entirely different thing because it is not available to them. Isn't there somebody that crosses that gap in your outfit here that says, "Why are you only ordering so much?" You might get some very illuminating information. They might tell you that, "If we order more, we can't get it; and this plane we are making for you is held up because we don't have enough to make it any other way."

Mr. GARRETT. We are going to try to get that answer, Senator.

Senator MALONE. How are you going to get it?

Mr. GARRETT. We are going to get it by going and asking these people.

Senator MALONE. Why do you not ask them like I asked them?

Mr. GARRETT. I think the first thing we have to do is find out what they have told the Air Force, because that only adds up to 35,000 tons. With that in our hand, we will go to these people and say, "You have indicated here that"—suppose a given company says they need 4,000 tons—"you need 4,000 tons."

Senator MALONE. Don't they mean when they say that that they want that amount of metal for the plane that has already been ordered from them?

Mr. GARRETT. I think so; yes.

Senator MALONE. Why don't you ask them how much they would need for the kind of a plane they are ready to make if they had the amount that they need?

Mr. GARRETT. Yes, we did ask them that.

Senator MALONE. You have asked them that?

Mr. GARRETT. This question was asked them and that is what the 35,000-ton figure was based on. That is what we tried to find out.

Senator MALONE. When was that?

Mr. GARRETT. A year ago, or a little more than a year ago.

Senator MALONE. It was only a year ago that I asked them that question.

Mr. GARRETT. I know. That is the thing we have not been able to trace down, why the difference between what they told us and what they told you. We have not traced that down.

Senator MALONE. Do you want to trace it right quick?

Mr. GARRETT. Yes.

Senator MALONE. One of them is coming in tomorrow. Do you want to talk to him?

Mr. GARRETT. I will be glad to.

Senator MALONE. I might have you both down here. It would be very interesting to me.

Mr. GARRETT. I would like to suggest getting another person down here, though, because as I explained before, when I am talking about requirements here, I am talking about something I have had no responsibility for and am only familiar with as an observer. I think it would be good to get the one that is responsible for them, and that would be either Carl Rolle or somebody that he would say was better equipped than he to answer questions.

Senator MALONE. Where is he?

Mr. GARRETT. In Mr. Pike's office, in the Office of the Assistant Secretary for Supply and Logistics. He can answer from his own knowledge of things that are done under his authority, and I can only answer for things that I have seen from the outside as an observer.

Senator MALONE. Would you suggest having Mr. Cullen here, too?

Mr. GARRETT. I think that would be useful.

Senator MALONE. That should be interesting. We know where the bottleneck is. It is in the ordering. But you say you are not responsible for it.

Mr. GARRETT. Well, I think you may misunderstand my position a little.

Senator MALONE. Well, it comes from the National Defense Administration.

Mr. GARRETT. I am not responsible for calculating requirements. I am responsible for trying to find out any technical bottlenecks in the use of titanium.

Senator MALONE. I understand that. This is the thing, though, that amazes me and mystifies me. Here are the manufacturers of jet engines, the manufacturers of airplanes, 3 or 4 manufacturers of airplanes, 4 or 5 manufacturers of jet engines, 3 at least, all testifying what they need in amounts of this material if they could get it and be assured that once they went into production they would have the amount necessary.

But in the meantime you have let a contract for a certain type of plane that only has a certain amount of titanium in it. And then you ask them how much titanium they need to manufacture the plane, the contract for which you have let to them; they tell you a certain amount and then you tell them down here that is the amount of titanium you want—not looking ahead to what you want to do, and not looking to what you need at all. Why is that?

Do you understand me?

Mr. GARRETT. I understand you completely, Senator.

Senator MALONE. I am just one of the hands around here, trying to do a little job for 95 other Senators. Why is it I cannot do it? Why is it I cannot get that information?

Mr. GARRETT. Senator, I think you are wholly right, that the responsibility for clearing up this——

Senator MALONE. It is over in the Pentagon. That is where it is.

Mr. GARRETT. Situation is in the Pentagon.

Senator MALONE. You agree with that; do you not?

Mr. GARRETT. I agree with that. My own personal difficulty in answering your specific question is that fortunately or unfortunately, as the case may be, I personally am not responsible for that area.

Senator MALONE. Then I just haven't got the right man here. That is the question I want answered more than anything in the world, just to help the program.

Mr. GARRETT. But I think, as a part of the work that we are doing, and that we are getting into, I think we may very likely uncover the answer to your question; and when we do, we will certainly bring it to the attention of the people who can do something about it over there.

Senator MALONE. Look, we are losing time.

Mr. GARRETT. On this question of time, you might be interested in a little thing that we have been working on this fall, on this new titanium organization. I mentioned the contract with Battelle that we had decided to make. The idea to make this contract first came up back in August. We don't yet have the contract although we have been pressing it just as hard as we could from the top level of the Department of Defense.

Senator MALONE. When did you start?

Mr. GARRETT. In August. With our ponderous mechanisms over there it seems to take that long to get anything done.

Senator MALONE. Well, we have wasted 10 years since World War II.

You might be interested in this, and you are perfectly welcome to have it, this testimony of October 22, in Henderson, Nev. Colonel McDonald was there from the Air Materiel Command at Wright Field.

Mr. GARRETT. Well, I knew that General Metzger wasn't handling it any more.

Senator MALONE. Who is handling it? Is McDonald?

Mr. GARRETT. I think he handles it among other things. I believe he handles all—I don't know, some general area. General Metzger, too. He wasn't solely concerned with titanium.

Senator MALONE. Yes, but he was a man of wide experience; was he not?

Mr. GARRETT. Yes, indeed.

Senator MALONE. Who is taking his place, really?

Mr. GARRETT. I believe that Colonel McDonald is in the position that General Metzger held.

Senator MALONE. Do you have an idea that he is experienced enough to push this program through?

Mr. GARRETT. I think the responsibility for this program was to a large extent assumed by General Metzger and I think to a considerable extent it has moved from Air Materiel Command to Washington. And I think the program is getting attention from Secretary Wilson and Anderson and Quarles and those people that it didn't get before. So I think it is getting attention in a different place. Perhaps General Metzger's loss won't be missed as much as it would have been.

Senator MALONE. Then you are just going to cut out Wright Field. They don't have any authority there. They do not help out. By slow-

ing down their orders or knowing how much they needed, it wouldn't slow you at all?

Mr. GARRETT. No, sir, you certainly need cooperation all down the line.

Senator MALONE. Here is a typical thing. It is all here and I think it would be interesting to you. I am trying to get some information as to what they are doing there.

Metzger asked if Mr. Hurley's statements stand up, and I told him what they were. It added up to 108,000 tons annually for engines and auxiliary parts. McDonald said that was right.

Now I am questioning Mr. Hurley, of Curtiss-Wright:

Senator MALONE. Then he says, Metzger says, "If Mr. Hurley's estimates stand up, I do not think we would buy engines unless we had airframes to put them in in the quantities you are talking about."

Douglas makes the airframes and cannot get it to make airframes out of. Now I say there, this is testimony taken last year:

Suppose the material were available. All you would need to do is forget availability of the material and defense and make airframes and engines you need and then his testimony would stand up.

General METZGER. Yes, sir.

"We say you would be talking about 200,000 tons of titanium in 1956."

Colonel MCDONALD. Yes, sir.

Senator MALONE. You are still talking about 35,000 tons.

Colonel MCDONALD. Again, Senator, I can only reiterate it is a question of quality. Right now the airframe people are not utilizing sponge production that is available at present.

Senator MALONE. I still cannot connect your testimony up with an order for the titanium you need and the alloys you need and laying down specifications and somebody refusing or unable to give it to you. You have never given an order.

Colonel MCDONALD. We have never had that demand existed.

Senator MALONE. I am exhibiting it to you now. Do you want to go down with me next week and visit Douglas and call another hearing?

Colonel MCDONALD. I would be glad to, sir, at your convenience.

Senator MALONE. I will tell you what you would find out and he would ask you and tell you that you need 150,000 tons of titanium for your airframes and your engines to make the planes you want. I suppose you want them?

Colonel MCDONALD. We certainly do. It is our primary interest.

Senator MALONE. I cannot connect your testimony up to trying to get it. What you are doing is saying you cannot make it so we will not order it. And the 35,000 tons is the most you have ever ordered.

So I get right back to the same thing all the time, just as today. You say Wright Field might be responsible; you say the Department of Commerce might be responsible.

Mr. GARRETT. I think you have misunderstood me on that.

Senator MALONE. Here I say:

Only recently has the Defense Mobilization Administration come up to 35,000 tons. The rumor around Washington is, and it is a great place for a rumor, that you had too much titanium.

You remember that, about a year ago. Of course, my grandson knew that was not true.

We called the committee together again and established the fact that the reason you had too much titanium was because you did not have enough for anybody to start using.

I did not outline this, but at that time Fleming gave an order not to sell any surplus until there was enough titanium to start using it and put it in the stockpile. We went on and on here for several pages and

got about all we got this morning. He did not know where the logs were jammed and he did not, apparently, know very much about it, and there was no order for any more. It is a very unsatisfactory situation.

Mr. GARRETT. Senator, I don't feel that it is as unsatisfactory as you have indicated.

Senator MALONE. What do you want to do about it?

Mr. GARRETT. I don't feel the situation is as confused or uncertain as you have indicated. I think there are specific reasons why we are not using as much titanium as these people indicate could be used; and I think those reasons are being very rapidly overcome. I think we are in far better shape today than we were a year ago when your hearings started.

I think a year from now titanium will be well on the road. But this testing work just has to be done before the engineers are going to go out and put it in their airplanes. I don't think the lack of availability of titanium is the answer. This is what you have been suggesting.

I think that is at least no more than part of the answer. There are some hundreds of pounds of titanium in the F–102 fighter. The quantity of titanium they can use is flexible, because they can put all of those 800 pounds in titanium, or half of it, or a quarter. In other words, they can use all the titanium available and put it into those airplanes.

Senator MALONE. That determines the weight of the engine, does it not?

Mr. GARRETT. I can give you a little story on that.

Senator MALONE. Does it not determine the weight of the airframe, and the weight of the airframe determines the size of the engine?

Mr. GARRETT. Yes; but this is all flexible. The F–102 was designed for a high-powered engine not currently available, and it was designed as a high-speed airplane with that high-powered engine. What they had to do for the first several dozen F–102's that were made, they had to put a lower power engine in that gave them low performance. Because they had low performance, they didn't get the heating problems contemplated.

So they were able to use aluminum in some places where they had counted on using titanium. I am bringing that out to show how flexible the substitution of materials can be.

Senator MALONE. It is flexible to the point now where you do not have the planes you have to have to defend this Nation.

Mr. GARRETT. This is right, but what I am saying is——

Senator MALONE. You are delaying the whole plan.

Mr. GARRETT. I don't believe the reason for this is because we have not made the titanium. I think it is the other way around. I think we have not made the titanium because we have these technical problems that we are very rapidly overcoming, and I don't think we have nearly as many today as we had a year ago. I think in another year we will be really ready to go into mass production of titanium. I don't think you could have, up until now, without having a lot of stuff on the shelf that you couldn't use.

Senator MALONE. What difference will that make in the production of sponge? If you are now meeting the specifications in sponge that you need when you whip these things, why do you not get at it and

produce it and get it ready so when you whip this thing in the alloys and in the matter of extrusion and in the matter of forges, you will have this stockpile of stuff?

Mr. GARRETT. I think they should.

Senator MALONE. Why do you not order it, then?

Mr. GARRETT. Do you mean 150,000 tons?

Senator MALONE. I do not know how much.

Mr. GARRETT. It is a question of how much.

Senator MALONE. But you are only ordering 35,000 tons, which is not a tenth enough according to all the testimony. So you, yourself, you tell me that you want to whip the shapes and alloys and forgings before you get the sponge available.

Mr. GARRETT. I believe, Senator, we can build up sponge production just as fast as we can whip the technological difficulties.

Senator MALONE. You are not going to whip them very fast, because you know how long it takes to let a contract and how long it takes to build a plant, do you not?

Mr. GARRETT. Yes.

Senator MALONE. How long does it take?

Mr. GARRETT. About 2 years.

Senator MALONE. Then you are going to have 2 years to spend after you whip the alloys and after you whip the extrusions and after you whip the forgings you have 2 years to build your plants, if you build them all at once, before you can get it. So the 2 years will be on top of the year you want here.

During this time, you could let this amount and save at least a year or 2 years, could you not?

Mr. GARRETT. Well, this year, our sponge production right now is only eight or ten thousand tons a year.

Senator MALONE. It is not that much. It is about 2,500 tons.

Mr. GARRETT. It must be more than that, sir, because——

Senator MALONE. Maybe you are buying some from Japan. I think what you are going to do—you have a deal on in New York now where you are going to end up buying your stuff from Japan. Of course, you cannot get it when the war starts. I think Russia right now knows more about it than we do. They have written 245 technical articles on titanium over in Russia, and they may be a long ways ahead of us.

Mr. GARRETT. The point I was trying to make, sir, was—let me draw a curve here. Anything like this has to come up on a rising curve. It can't jump overnight to the full production.

Senator MALONE. I am not talking about jumping. You know, for example, they are now meeting the specifications of the 140 or 150 hardness, and all that sort of thing, do you?

Mr. GARRETT. That is right, on sponge.

Senator MALONE. If you could make that sponge that meets the specifications that you will need when you whip the fabrication, why do you wait until you whip the fabrication and then take 2 years to build a plant to make the sponge?

Mr. GARRETT. I think the things have to go along together and I think they are going along together. You say we have production now of some possibly 5,000 tons a year of sponge.

Senator MALONE. We have about 2,500 tons.

Mr. GARRETT. All right, we have 2,500. We have contracts with plants now building to raise that to 10 times that figure.

Senator MALONE. I do not think you do. I have it in my office. It is classified, but I am sure you do not. Every week we get it, and we know the status of the negotiations and we know when they close them up.

Mr. GARRETT. The figures on contracts that have been made are not classified.

Senator MALONE. Put them in the record. Get them for us and put them in the record. You are not up to your 35,000 tons.

(The information referred to follows:)

GENERAL SERVICES ADMINISTRATION,
EMERGENCY PROCUREMENT SERVICE,
Washington 25, D. C., December 15, 1954.

Hon. George W. Malone,
United States Senate, Washington 25, D. C.

DEAR SENATOR MALONE: During the titanium hearing on December 8, you requested information as to the dates of the various titanium expansion contracts. This information follows:

Contract No.	Contractor	Effective date
GS-OOP (D)-12047	Titanium Metals Corporation of America	Aug. 1, 1951
DMP-6	E. I. du Pont de Nemours & Co	July 24, 1952
DMP-75	Crarret, Inc	July 31, 1953
DMP-99	The Dow Chemical Co	July 8, 1954
DMP-100	Union Carbide & Carbon Corp	Sept. 14, 1954

If we can be of any further assistance, please call upon us.

Very truly yours,

A. J. WALSH, *Commissioner.*

Mr. GARRETT. No, sir, I didn't say we were; but I say we were approximately 10 times the 2,500 figure—we are approaching 25,000 tons in actually contracting for it.

Senator MALONE. I do not think you are that high.

Mr. GARRETT. It is 23,100, I believe, the actual figure.

Senator MALONE. I believe it is something like that. But the figures you bandy about, 5,000 tons a year we are making and 10,000 tons more than that under contract, would not make any sense at all. I am not blaming you. I am just down here to get information.

But I again leave it with you, and I want you to read this and let me get it back. If you think we are making sponge now that meets the specifications, and if we are not let us improve the specifications—the first you let was over 200 hardness and it did not prove to be usable. That was no one's fault because you were shooting in the dark.

But if 140 or 150 or 160 meets it and the manufacturers are meeting it, then why do you not let the contract? Why do you not send down to Mr. Fleming the amount you need and let him change his objective, his goal, so that if it is 150,000 tons or 500,000 tons or 45,000 tons, tell him, because his goal now is 35,000 tons. He is not confining himself to that, he says, but you have no information from the top of the pyramid, and that is you and Mr. Wilson.

What would you do about that? Would you not give the man some information on it? Tell what you need and not say that "We do not want to make any other until we check."

"We know we are going to whip the alloy thing, and the forging and alloys, but wait until we do it. That will take a year. Then we will let the contract."

Mr. GARRETT. I would like to say something more about sponge quality, Senator. I think we can be perfectly sure that any sponge going into the stockpile today will not be what is wanted 5 years from now. In other words, it will be obsolete in 5 years.

Senator MALONE. Then do you want to wait 5 years before you increase production?

Mr. GARRETT. No; but what I am saying is that I think 35,000 tons now is adequate to fulfill any possible timely needs of the aircraft industry. I think next year we can go to 100,000 tons if that is the figure.

Senator MALONE. But you lose that year; do you not?

Mr. GARRETT. No; we don't lose that year because we are not ready to use that much.

Senator MALONE. But you will be ready to use it before you build a plant, and that will take 2 years?

Mr. GARRETT. I don't think so, Senator. I don't think we will be ready to use 100,000 tons within 2 years.

Senator MALONE. I am talking about 40,000 tons, anything more than the 35. You are stymied now. All I ask you to review is whether you want to wait and tell him the amount you want to use, to raise the amount, so that they can raise their sights on letting contracts.

You know, you can change your specifications as you go along by simply arranging with the company with which you have the contract. It may cost you a little money for making that difference. But at least you have him in production.

Why, when it takes 2 years to get into production, to let a contract taking 3 or 4 months, or it has so far, 2½ years following the time you whip the thing and know that you are going to need more and know specifically how much, then you have lost the year or 2 years it took you to determine that. You are now getting ready to let to the Battelle Institute a contract, and I hope you let it to several others, too, to find out how to fabricate and how to do these things.

You, yourself, say that will take a year or two.

Mr. GARRETT. That is right.

Senator MALONE. Then you wait and put 2 years on top of that, in getting ready to manufacture, in building the plants.

Mr. GARRETT. I don't see it that way, Senator.

Senator MALONE. What would you do?

Mr. GARRETT. I don't think you and I are really in disagreement, except for the matter of timing to a slight degree. I think there is a time when we need to go beyond that 35,000 tons. Maybe it is right now. But that 35,000-ton figure was set initially 3 years ago. It was confirmed last year. Maybe another look at it——

Senator MALONE. Last year they knew better than that.

Mr. GARRETT. Another look at it which they are making now may bring it up. But it will be a good 2 years yet before we are in a position to use 35,000 tons.

Senator MALONE. Then you want at that time to let the contracts and be 2 years before you can produce it. Is that what you want?

Mr. GARRETT. We have let the contracts for 35,000 tons.

Senator MALONE. No; you have not.

Mr. GARRETT. We have told the Office of Defense Mobilization that that is what we want.

Senator MALONE. I am talking about the 140 or 150.

Mr. GARRETT. Maybe today, maybe this fall is time to go beyond the 35,000 set it at 60,000. Maybe a year from now it goes up to 150,000. But it is a question of timing, as I see it.

Senator MALONE. Suppose you had set 150,000 tons a year ago. You would have it licked; would you not?

Mr. GARRETT. We wouldn't be able to use it.

Senator MALONE. You would be able to use it if you had it? Why do you not see Gross and Douglas?

Mr. GARRETT. I haven't talked to Gross and Douglas, but I have talked to the materiel people who would use the stuff.

Senator MALONE. They tell me if they had it they would use it, and you are telling me they can't use it.

Mr. GARRETT. I am saying they have to overcome these remaining technicalities before they can use it.

Senator MALONE. Some of them know how to do it.

Mr. GARRETT. I don't think they do. I have every confidence that we will use it, but I don't think we would use it today if we had it.

Senator MALONE. You do not think you would use it next year if you had it?

Mr. GARRETT. Not that much. I think we would use a good number of tons if we had it.

Senator MALONE. Two years from now?

Mr. GARRETT. I think in 2 years——

Senator MALONE. Then you would let the contracts so you would have it 2 years from then.

Mr. GARRETT. I just finished saying that perhaps this 35,000-ton figure should be revised upward now. I say perhaps because it is another person that works on that and not I.

But talking about it philosophically, I say that I think the 35,000-ton was a good figure when it was set. I think it is time to review it and to reset the figure.

Senator MALONE. If you think in 2 years from now you can use 100,000 tons, would not now be the time to let the contracts for it, so that in 2 years from now you would begin to produce it?

Mr. GARRETT. I think 2 years from now we will not be able to use 100,000 tons.

Senator MALONE. I am sure you would not, the way you are progressing. You can if you have it.

Mr. GARRETT. Well, you raise this question of forging. Nobody in the aircraft industry is going to put a forging in an airplane that they do not think will stand up. This is what happened to the Comets. They failed in fatigue and the whole airplane blew apart.

Senator MALONE. You do not think you could use it now if they had it?

Mr. GARRETT. I don't think they could use it today if they had it. I think they will use it—I think it will be a steeply rising curve. I think it will be something like this one. I think we are down here now [indicating] and I think the thing is going to go up very steeply.

Senator MALONE. Why are you down there now? I will tell you why. It is because of the very attitude you are now taking.

If you had had people in charge of this thing for the Government that had any vision in the thing, you would not be down there now.

Mr. GARRETT. Let me put it this way: Here is 1949 when the picture started, and here is 1954 [indicating]. If this were a commercial enterprise and the Government had not taken the steps it had we would not be here until around 1970 or 1975.

So by what we have done in the Government, we have advanced this stage from 1975 to 1954. I think that is doing pretty well.

Senator MALONE. It would, if it wasn't about 3 years too late. You are getting ready for something that may be already fought by the time you get it.

Mr. GARRETT. Our policy, Senator, is to push titanium just as hard as it is possible to push it and to put money in where it is needed to overcome these difficulties.

But setting up a production goal that is beyond the speed with which we can expand the industry isn't going to advance the thing any.

Senator MALONE. I am assuring you, and this is the evidence we have, that any titanium you do not need, if you can release it on a steady basis in amount, civilian industry will take it. You do not have to worry about that.

Mr. GARRETT. As I said before, I don't think titanium should be rationed. I think civilian industry ought to be able to get all the titanium they can take.

Senator MALONE. So why worry about production until you are ready with another 2 years of experimentation? Here is the thing some of us would like to see. When we get it to the point where production is more than what you need in your War Department and national defense in case of war, we do not worry about it any more. It is no longer a critical material. So why don't we go to work on it on that end if you are not ready to use it?

Mr. GARRETT. This is up to industry; is it not?

Senator MALONE. No, it is not, because it is rationed. You have prevented it from being used in industry. Now you are getting ready to buy it from Japan. First you were selling it to England. We will fool around here until finally the Japanese, of course, who can produce it cheaper than we can, will be selling it to you.

I wish we had a map. It makes things look so ridiculous. In Henderson, Nev., do you know where they are getting the raw material to make the titanium?

Mr. GARRETT. From Australia.

Senator MALONE. Yes, and you could not get a pound of it the morning after the war starts. One thing the Bureau of Mines is doing is starting its investigations now in laboratory experiments to switch over in peacetime to use ilmenite. There is more ilmenite in the United States and southern Canada than you can use in a thousand years. Over in New Jersey they are getting most of their ilmenite from India.

Do you fellows pay attention to that part of the program so you might continue to make titanium even after the war started?

Mr. GARRETT. Yes. I think the ultimate source of titanium will be the ilmenites such as they are producing up in Quebec.

Senator MALONE. I think they can do it in the United States as in other places. Kennecott Co. testified, and it is one of the best companies in the world, that they make titanium slag—up to 70 percent, I think it was—and they have a pig iron. If they could sell titanium slag, it would be profitable to make the pig iron. The whole operation would be profitable. Still we import it from Australia.

We will recess now until 3 o'clock.

I think that is all we need from you, Mr. Garrett. We appreciate very much your coming down. Your testimony will be returned to you. If you can help us on one or two of the points where we seem to be stymied, we would appreciate it.

We will start tomorrow morning at 9 o'clock.

We will reconvene this afternoon at 3 o'clock.

(The following was subsequently received for the record:)

REPORT ON STRATEGIC AND CRITICAL MATERIALS

Office of the Assistant Secretary of Defense, Research and Development

Approved: Donald A. Quarles, Assistant Secretary of Defense (Research and Development)

This statement is in response to a request for information regarding the role of research and development in futhering the most efficient utilization of strategic and critical materials. Much of the material in this statement has been excerpted from the Annual Materials Conservation Report for 1953, which was published by the Office of the Assistant Secretary of Defense for Supply and Logistics.

The Assistant Secretary of Defense for Research and Development recognizes his important responsibilities in assuring the most efficient utilization of our material resources in military equipment. Since most of the critical or strategic materials represent irreplaceable assets, their expenditure in military items and equipment must be most prudently invested. The crucial importance of our material resources to our national defense, and our economy as a whole, is well documented.

Two of the most important responsibilities of the Assistant Secretary of Defense for Research and Development in this area are:

1. Assuring that in the original development and design of military weapons and components the most effective use is made of all materials.

2. Performance on a continuing basis of research and development in the broad field of materials to obtain acceptable alternates which will obviate, or at least mitigate our dependence on critical and strategic materials.

In addition, the Assistant Secretary of Defense for Research and Development encourages the free interchange of research and development information on materials programs.

Advising and assisting the Assistant Secretary of Defense for Research and Development on these matters, as well as on other materials problems, is the Technical Advisory Panel on Materials, comprised of men eminent in the various fields of materials research and technology.

When special studies or investigations are required to develop information on which to base policy decisions or operating procedures relating to materials problems, the Materials Advisory Board of the National Academy of Sciences serves the Assistant Secretary of Defense for Research and Development on assigned projects. In the past 3 years, the MAB has conducted surveys and issued reports on 56 projects, including such subjects as nickel, titanium, and materials conservation in jet engines. These reports provide information and recommendations of great value, not only to the Assistant Secretary of Defense for Research and Development, but also for the Assistant Secretaries for Applications Engineering and Supply and Logistics, as well as the three military departments, Office of Defense Mobilization, and other departments and agencies concerned with our materials resources welfare.

The Assistant Secretaries of Defense for Applications Engineering and Supply and Logistics have responsibilities for critical and strategic materials as related to engineering and production of end items, establishment of requirements, pro-

curement, supply, stockpiling, specifications, and standards. An important aspect of the work of the OSD relative to strategic and critical materials concerns the calculation of quantities required to meet mobilization schedules and work with Office of Defense Mobilization, through membership on the Interdepartmental Materials Advisory Committee and otherwise, on means of providing the quantities estimated to be required.

The three military departments, Army, Navy, and Air Force, are all of course, engaged in research, development, evaluation, and engineering on materials as applied to military equipment under their cognizance. Theirs is the responsibility for implementing the policies established by the Secretary of Defense and his assistants.

The basic principles of the Department of Defense materials conservation program may be briefly summarized as follows: Conservation is not a compartmentalized function but an aspect of every job responsibility in the Department. It is a frame of mind, an attitude, expressed broadly as the balanced, prudent use of the entire resource pattern available for defense. The focus of the program is first upon mobilization readiness and secondly upon reduction of current impacts of defense programs upon the national economy. The procedures of conservation are based not upon nonuse but upon the best use of each pound of each material. The program emphasizes most the conservation of those materials most likely to restrict essential production in time of emergency; it emphasizes conservation of those materials in items in which they find their heaviest use.

The Bureau of Mines, Department of the Interior, carries on research on extraction processes. Their program is toward the utilization of low-grade ore and reclamation of byproducts and slurries.

Within the military departments one of the primary consumers of critical materials is the jet engine, with its requirement of reliability while operating under extreme temperature and stress conditions. To meet these conditions, particularly when this type of engine was completely new to the industry, it has been the practice to use rich alloys in order to assure the maximum performance. This, of course, would be likely to limit the number of engines that could be furnished under full mobilization within the maximum available quantities of chromium, cobalt, columbium, molybdenum, nickel, and tungsten. The Air Force, and later the Department of Defense, established target limits for these critical materials used in jet engines in order to assure sufficient materials for the number of engines required for full mobilization. This arrangement promotes the conservation of all of these critical materials, balancing the quantities so that a large quantity of one critical material is not used in order to decrease the use of another. It effectively promotes the efficient utilization of critical materials.

The Office of the Assistant Secretary of Defense (Supply and Logistics) has issued conservation directives, one of which is the Comparison of Long-Range Scarcity of Certain Materials, which assigns a "relative scarcity number" to each of the critical materials. By the use of this device it can be determined whether the use of various amounts of one material or another is best serving the conservation requirements. Along with this program some engines have been made and tested which employed the use of alternate, less critical materials to determine the actual performance of this type of construction. At present this program is being reviewed and coordinated between the Air Force and the Navy Bureau of Aeronautics, with a view to making changes where necessary to keep pace with new designs and changing availability of materials.

The Materials Advisory Board has made and submitted detailed reports on most of the critical materials. These reports are basic in the conservation program as they, in general, cover the supply and demand aspects as well as give recommendations for their proper use, the use of alternate materials, and suggest lines of research which will ultimately provide for their most effective use for mobilization. The recommendations of the reports are brought to the attention of the military departments, and, when applicable, to other agencies of the Government, for implementation. The report on the Conservation of Nickel for Full Mobilization (MMAB–39–M), is an excellent example of the MAB's work. In addition to the individual reports on critical materials, the MAB has made reports on Conservation of High Temperature Materials (MAB–5–M) and Materials for Use in Gas Turbines (MAB–41–M). These reports deal with the problem of high-temperature alloys using the critical materials listed above.

Guns are another important consumer of critical materials. There is a continuous effort being made to improve the performance of guns and at the same

time improve their mobility. This is done by using materials with high-strength characteristics and, in general, this requires alloys containing critical materials. Both Army Ordnance Corps and Navy Bureau of Ordnance have research programs to make the most efficient use of critical materials while increasing strength and reducing weight where possible. The MAB has made a study of materials in the 3-inch .50-cal. gun mount for the Bureau of Ordance and has suggested target limits similar to those in jet engines. The materials involved are chromium, copper, manganese, molybdenum, nickel, and tin.

Army Ordnance has several research and development projects aimed at the conservation of critical materials. These cover both the use of leaner alloys and changes in design. An additional problem in our present specifications is the requirement of withstanding impact at low temperature. This, of course, requires considerable research and development effort to find the leanest alloy and best design to withstand severe environments. A very important saving in critical copper has resulted from the development of steel cartridge cases.

Along with improvement in guns comes the inevitable need for improvement in armor. Our requirements have become increasingly severe during and since World War II. Low-temperature performance, as well as the ability to defeat more powerful weapons, is now a requirement. Here again, development of lean alloys without loss of performance has been the goal. Use of boron in many alloys has contributed to success in this effort.

The developments in armor have brought about requirements for improved projectiles. This again has started with the use of relatively rich alloys, but extensive research has been carried on to make these alloys leaner. In general, manganese, nickel, chromium, molybdenum, and vanadium have been used. In an effort to conserve the more critical materials, boron has again been used. In certain types of projectiles tungsten, cobalt, and nickel are used. Work is being carried on to try to reduce the quantity of these critical materials required; but the prediction of future requirements in this field is uncertain, and at present no great improvement can be seen.

Vehicles and aircraft require large quantities of critical mtaerials. In some items the alloys are relatively lean but the items are required in such large numbers that the quantities of critical material required are actually greater than those used in other components requiring rich alloys, but used in smaller quantities. Here again, boron steels are being evaluated. In aircraft, the advance in operational requirements calls for materials of high strength at elevated temperatures. It is hoped that titanium will ultimately provide for certain applications an abundant material to relieve the demand for more critical materials.

In the electronics field, materials that demand particular attention are mica, quartz crystals, selenium, block talc, and germanium. Active conservation projects are underway on the first three of these items, in addition to research and development to find substitutes and improve performance. Synthetic mica and synthetic quartz crystals have been developed and evaluation of these materials is progressing favorably. Substitutes for block talc are presently in use by some manufacturers. Research is in progress on both the uses and the producing of germanium. Because of the importance and value of the above materials to the electronics industry, much of the research and development pertaining to them is carried on directly by industry.

Certain materials which do not fall directly under any of the above fields should be considered in the conservation of critical materials.

Industrial diamonds, for which we are completely dependent on foreign supply, are of vital importance in certain machining and grinding operations. A small amount of research and development work has been accomplished, but none has shown substantial promise for the synthesis of diamonds. The most promising field for diamond conservation is in the development of new processes for machining and grinding. The Materials Advisory Board has made two reports on this subject, the latest being MAB–54–C of July 1, 1953. In this report it is pointed out that industry is carrying on the bulk of research in this field and that the Department of Defense does not need an extensive program. However, it is emphasized that proper design of end items can reduce the number of costly machining and grinding steps in production.

In the remaining portion of this report, materials are arranged throughout in the order of the importance attached to the conservation of each, in the judgment of the Office of the Assistant Secretary of Defense (Supply and Logistics).

The materials considered to deserve the highest priority of conservation attention are:

Nickel	Copper
Molybdenum	Chromium
Abaca	Cobalt
Tantalum	Waterfowl feathers and down
Selenium	Columbium
Amosite asbestos	

Conservation of other materials should not be abandoned; but efforts to conserve them deserve reduced priority, in terms of effort and money expended. Heavy emphasis, in terms of numbers of active and completed conservation programs, was given to a majority of the materials on the above 'priority" list. However, in the cases of abaca, tantalum, selenium, amosite asbestos, and waterfowl feathers and down, a more intensive and aggressive effort would appear to be warranted. This judgement is offered on the basis of strategic availability of materials for mobilization, and not on the basis of dollar economies offered. Still, the effort to conserve materials is sometimes rewarded doubly by a savings of both materials and dollars.

In order to call attention to the need for a continuing research and development program in preparation for conditions which will be faced under full mobilization, the Technical Advisory Panel on Materials in the Office of the Assistant Secretary of Defense for Research and Development has transmitted a memorandum to both the Coordinating Committee on Ordnance and the Coordinating Committee on Piloted Aircraft, calling their attention to the problem of producing a large volume of equipment with limited quantities of critical alloys and recommending that adequate provision be made in the research and development program for continuing development of alternate materials.

In addition to its responsibilities for reducing military requirements for strategic and critical materials in scarce supply through conservation activities, the Department of Defense has been assuring that parallel steps are being taken to expand supplies of scarce materials. Requirements for all strategic and critical materials are periodically estimated and sent to the Office of Defense Mobilization for the use of that agency in formulating programs designed to expand United States productive capacity for scarce materials or, where necessary, to provide additional supplies of materials for a period of war through stockpiling under the Strategic and Critical Materials Stock Piling Act. The Department of Defense, through its membership on the ODM Defense Mobilization Board and on the ODM Interdepartmental Materials Advisory Committee, keeps in close touch with the progress of materials expansion programs to insure that appropriate emphasis is being given to meeting urgent military needs. The civilian agencies have undertaken a number of programs for expansion of supply under authority of the Defense Production Act of 1950 as amended, the Internal Revenue Codes of 1950 and 1954, the Strategic and Critical Materials Stock Piling Act, and other legislation. The hearings held by the Special Senate Subcommittee on Minerals, Materials, and Fuels Economics in 1953 and in 1954 brought out many of the details of these expansion programs.

MATERIALS CONSERVATION SUMMARIES

Nickel

Of all the materials on the Department of Defense Materials Conservation List, nickel comes closest to being a true "war metal." It deserves first priority among materials receiving conservation attention. Since the start of the Korean war, nickel has remained the world's most critical material; this condition is likely to continue for some time.

The potential available supply of nickel has been materially augmented by actions under the Defense Production Act for which commitments of over $878 million have been authorized. Consequently, a broader production base with expanded production facilities in Canada, Cuba, and the United States has been achieved. Additional supplies are anticipated as Government-assisted projects come into production. Pilot-plant operations on Cuban ore, now under negotiation, may further increase the production potential.

Thus during two world wars and the Korean emergency, nickel was in short supply because of the exceedingly large military requirements. Despite the expected increase in production brought about through Government action (50 percent for 1956 over 1950), a new mobilization period will most probably find

the United States once more short of nickel. This shortage is the consequence of technological development in the field of high-temperature alloys and higher performance requirements upon alloy steels. It must be recognized that nickel possesses remarkable properties that it can impart to its alloys; no effective substitutes have been found. The new alloys continually being developed in the high temperature field usually require nickel, and in increasing percentages. It is therefore imperative that this metal be used most wisely, that nonessential uses be everywhere curtailed, and that all nickel-bearing scrap be carefully segregated and returned to industry through proper channels as a systematic procedure in peace or war.

Conservation of nickel was stressed during 1952. There were 170 projects to conserve nickel that were completed in that year, yielding savings of 8,998,329 pounds, and an additional 165 projects were active at the close of the year. Principal projects dealt with reduction of nickel in armorplate, conversion from the use of austenitic to chrome stainless steels, development of uses of boron steels, replacement of 70 percent copper 30 percent nickel with 90 percent copper 10 percent nickel, and investigation of such alternative materials as manganese stainless, reinforced plastics, aluminum, and magnesium. Corrosion-resistant coatings, principally ceramics, were being increasingly attempted.

Of the 168 projects completed in 1953, the largest single number (58) accomplished the substitution of chrome stainless steel in place of austenitic stainless. Carbon steel was substituted for alloy steel in 29 projects and for stainless steel in 8 projects. The conservation of nickel was obtained by a reduction in alloy content in 28 projects. Boron steels were used in place of alloy steels in 11 cases. Other substitutes for austenitic stainless steels were plastics or reinforced plastics (10), aluminum (4), brass, malleable iron, alloy steel, bronze, and magnesium. In four projects the percentage of nickel of a stainless steel was reduced. Two projects used ferritic welding electrodes in place of austenitic electrodes. For monel, chrome stainless steel was substituted in 2 projects and aluminum in 2. For nickel silver, chrome stainless steel was used in 2 projects, brass or bronze in 3. For 70–30 cupro-nickel, an iron-modified 90–10 and reinforced plastics were used. Ceramic-coated stainless steel was used to replace inconel. Ten projects involved revised fabrication process, six a change in design, and other projects concerned the monitoring of industrial practice, scrap recovery, and research into substitutionability.

Of the 86 projects still active at the close of 1953, reduction of alloy content is proposed in 26, the use of carbon steel for alloy steel in 2, the use of boron steel for alloy in 6. Substitutions proposed for austenitic stainless steels are chrome stainless (9), reinforced plastics (7), aluminum (7), manganese-type austenitic steels (5), carbon steel (4), ceramic coating on carbon or low alloy (4), plastic (2), rubber-coated carbon steel and magnesium (1 each). One project involved substitution of ferritic electrodes for austenitic. Other projects were substitution of silver alloy for nickel, use of 90–10 cupro-nickel for 70–30, substition of aluminum, plastics or coated steel for cupro-nickel, plastics for monel, and investigation into powdered iron, ceramic-coated austenitic stainless for high-temperature alloy. Process changes were proposed in 14 projects and design changes in 14.

Molybdenum

About 90 percent of the world's molybdenum is produced in the United States, but depsite this favorable supply position, mobilization requirements would exceed available supply, and the metal is being stockpiled. With the trend toward higher melting points demanded of high-temperature alloys, the prospect is that requirements for molybdenum will tend to rise correspondingly. Emphasis on conservation of molybdenum deserves high priority. This is particularly true as the stockpile of molybdenum is not yet in a satisfactory position. Because of the special properties of molybdenum respecting high temperature uses, it is believed that emphasis on conservation should be directed to other applications to free molybdenum where possible for those in which it is unusually well suited.

United States production of molybdenum has been expanded from 28 million pounds in 1950 to 57 million in 1953. The 1954 output has been at a similar high rate, amounting to 37 million pounds for January–August. Substantial quantities of molybdenum are being added to the stockpile, and a reasonably satisfactory position should be attained by 1956. This expansion has been made possible by Government contracts which have permitted exploitation of submarginal ores as well as normal grade ore bodies. Gross transactions under the Defense Produc-

tion Act amount to $159 million, and the ultimate cost to the Government is estimated at $24 million.

In 1952 the military departments reported 86 projects to conserve molybdenum, of which 23 were completed with savings of 232,624 pounds, and another 63 projects were active at the close of the year. In 1953, the scope of molybdenum conservation effort was enlarged.

The only project yielding any current savings of any consequence was by the Army in conjunction with the Caterpillar Tractor Co., to replace alloy steels with lower alloy and boron steels, which yielded a savings of 19,162 pounds. However, it should be noted that reduced levels of procurement result in reduced current yield from conservation projects completed; thus, there were at least 17 completed projects to conserve molybdenum in which no procurement took place of the item affected during the period of this report, and reduced levels of procurement occurred in many additional items.

Of the 59 completed projects, 26 effected a reduction in molybdenum content of the alloy by use of a lower alloy (using boron in 11 reported instances), and 23 went from alloy steel to carbon steel; 7 projects made use of a process change and 3 used a redesign of the item. Of the 30 projects under study, 8 propose the substitution of carbon steel for alloy steel and 6 propose the use of boron steels; 5 aim at redesign.

Abaca

Abaca is a tropical hard fiber grown chiefly in the Philippine Islands and in Central America. It is used chiefly in high-grade rope and to some extent for high-strength paper, such as is used for mimeograph stencils. It is preferred for marine cordage because of its strength and elasticity, as well as its resistance to swelling and to damage by immersion in salt water.

The United States is dependent on foreign sources for all its supplies of abaca and other hard fibers. Abaca has been designated as a strategic and critical material and a national stockpile of abaca has been established. Abaca constitutes an actual bottleneck material in time of mobilization, and it has therefore been included on the Department of Defense materials conservation list. It is not possible to stockpile the full amount of abaca that would be required, over and above imports, in time of national emergency, as the fiber becomes brittle in storage. It is necessary to rotate the abaca stockpile completely, at least once every 5 years, which limits the size of the stockpile to the amount of abaca of stockpile grades that it is feasible to move into normal industrial uses in peacetime.

The impracticability of stockpiling an adequate war reserve of abaca made it essential to undertake supplemental program to augment supply. The Abaca Production Act of 1950, sponsored by the Department of Defense, authorized the Government to expand the abaca acreage in Latin America to 50,000 acres from the 25,000 acres under abaca cultivation in Central America at that time. However, owing to economy measures and also to difficulties in disposing of current production of abaca at a satisfactory price to private consumers in 1953–54, the Central American abaca plantings have been cut back to between 20,000 and 21,000 acres. The plentiful supply of abaca at this time undoubtedly has influenced a curtailment in abaca plantings in Latin America. Thus, it has tended to reduce the supply available from current production in event of emergency. To increase the supply of hard fibers by planting additional acreage at the outset of a 5-year war would offer limited possibilities. To develop new areas for planting in the tropics takes considerable time; even after planting, the first crop takes about 2 years. Therefore, although abaca is now readily available, it is likely to be in very short supply in a prolonged war. Energetic measures are necessary to bring mobilization supply and essential demand into balance.

During World War II, when the Philippine Islands (source of 98 per cent of prewar world production of abaca) were cut off from the United States, a wide variety of substitute materials were made use of. They included sisal, hennequen, cotton, jute, American hemp, and various combinations of these, sometimes with steel cores. A large acreage in Middle Western States was planted in domestic hemp and 42 hemp mills were built by the Government. All in all, the shortage of abaca proved quite costly. World War II also saw the emergence of nylon as a fiber with unusual strength, elasticity, and durability, but substantially more costly than abaca. Owing to the many other priority uses for nylon, rather limited quantities of this fiber are likely to be diverted to rope-making in a future war emergency. The most obvious natural fiber to replace abaca would be sisal. (Abaca has a scarcity number of 96 and sisal has a number of 18.4.) However,

in addition to being a less satisfactory material for rope-making, sisal is also likely to be in short supply. The next most likely natural substitute is hennequen, but there is not likely to be any significant excess of hennequen as a substitute for either sisal (in baler twine) or other applications.

Only one abaca conservation project was reported in 1952. This was a completed project by the Department of the Army which, by resorting to a smaller size of rope, a savings of 12,000 pounds of abaca were conserved during 1952 procurement.

As a result of research investigations, a preservative treatment has been developed which extends the shipboard service life of abaca rope 20 percent. Nylon has been adopted as standard for mooring lines for submarines. Nylon towing lines are presently undergoing service tests in United States east and west coast areas, as well as in tropical and arctic environments. In a service test, a nylon hawser outwore 45 manila hawsers. Because of the greater strength of nylon, Navy, in its test, substitutes 3½-inch-nylon lines for 5-inch manila, 2¾-inch nylon for 3½-inch manila, 2½-inch nylon for 3-inch manila. Nylon costs $2.40 per pound, or about $0.86 per foot of 3½-inch nylon; manila costs $0.36 per pound or about $0.27 per foot of 5-inch manila.

Other synthetic fibers, such as dacron, orlon, saran, polyethylene, and fortisan, are also being evacuated. Dacron in tests thus far conducted looks very promising.

Of the natural fiber substitutes for abaca, sanseveria looks more promising than others tested. In cooperation with the Navy, the Department of Agriculture has 50 acres of sanseveria under experimental cultivation in Florida to determine the feasibility of growing this crop in the United States.

Tantalum

Tantalum is a small-volume metal used both as ferroalloy additive and in the pure form. It is produced as a byproduct in the mining of columbium, beryllium, mica and tin; world reserves of the metal are very limited. It comes mainly from Africa with some additional imports from Brazil. Its high price has tended to discourage its use except where its properties contribute importantly to performance. Under mobilization, direct military requirements for tantalum would amount to some four-fifths of all essential requirements and indirect military uses would probably take half of the remainder. It is used in the electronics industry to make capacitors, in surgery, and in jet engine applications in combination with columbium to stabilize stainless steel against high-temperature corrosion.

In order to overcome an estimated mobilization deficit of tantalum a stockpile objective has been established but the present status of the tantalum stockpile is not satisfactory. Aggressive measures are currently underway to improve the supply situation. Although conservation possibilities in tantalum are naturally limited, such measures as are possible to reduce military dependence on this material deserve a high priority.

Only one project, a control measure by the Air Force to restrict jet engine applications of columbium-tantalum, was reported in 1952. In 1953, this project was continued and two additional projects were reported—both by the Air Force—one of which was completed and the other in development. The completed project concerned arrangements for recycling high temperature alloy scrap (containing tantalum among other metals) generated at Air Force installations. The project under development proposed research to develop a micronic capacitor in which glass was substituted for tantalum.

Selenium

Although military programs received all needed selenium during the past few years, supply has continued to be insufficient to meet all requirements, including those to meet national stockpile objectives. Any increase in supply is likely to be taken up by increases in essential requirements—especially with respect to high-purity selenium used for dry-plate rectifiers in electrical and electronic equipment. Thus, the outlook for closing the mobilization supply-demand gap in selenium is not good. The present stockpile has for some time remained in an unsatisfactory position.

Under the circumstances, conservation of selenium through development of substitutes, redesign, and intensive measures of scrap salvage, should be given high priority by the military departments. Research on titanium, silicon, and other metals appears to indicate good possibilities for the development of new rectifier units using selenium.

The Government expansion program for copper, discussed elsewhere in this report, is expected also to add to the supply of selenium, which is produced as a byproduct of electrolytic copper refining. Substantial increases in selenium supply are expected to occur from this source within the coming year. In addition, the General Services Administration has introduced a program for the collection of damaged selenium rectifiers from both military and civilian agencies and for recovery of selenium from this scrap material for addition to the national stockpile.

Only one project was reported in 1952, and this project was continued throughout 1953; it concerns investigation of titanium and other metals as substitutes for selenium in rectifiers.

Asbestos

Asbestos is a fibrous mineral. Amosite asbestos, coming entirely from South Africa, is a long, coarse fiber used chiefly in insulation. The principal military use of this fiber is for naval steam blankets and other types of heat insulation related to propulsion machinery. For these military applications a technically suitable substitute has been found in fibrous glass; however, glass fiber continues to be materially higher in cost than amosite asbestos. As long as the cost of glass fiber prices this alternate out of steam blanket uses, and glass fiber producing facilities continue inadequate to replace amosite asbestos in addition to other wartime needs the necessity to develop a feasible solution to the amosite supply-demand unbalance will continue.

This is one of the materials being stockpiled. There is only one commercial source, located in South Africa. Only small quantities are obtainable for addition to the stockpile.

No projects to conserve amosite asbestos were reported in either 1952 or 1953.

Copper

During the Korean emergency, the guns-and-butter economy required copper in such large amounts that domestic mines and foreign imports were unable to meet the total demands of industry. This demand, coupled with strikes in the domestic mining industry, resulted in some withdrawals from the national stockpile.

United States domestic mine production of copper is being increased through the medium of guaranteed market contracts made under authority of the Defense Production Act. It is expected that in the next few years approximately 250,000 short tons of annual capacity will have been created under these guaranties that might not otherwise have been brought into production. Expansion commitments for copper involve over $940 million in borrowing authority.

Great strides have been made in military conservation of copper, particularly in ordnance. Substitution of steel for brass in most artillery sizes of cartridge cases has made available quantities of copper for electronics, guided missiles, and other important programs. However, the total supply of copper for mobilization cannot be greatly increased except through stockpiling, and overall requirements are very large. Consequently, continued conservation effort must be exerted to insure efficient use of the metal.

In 1952, a total of 79 projects were completed and 94 remained in progress at the close of the year; savings, including scrap recovery figures reported by the Air Force, amounted to 13,352,034 pounds.

Projects yielding major savings of copper during the year were, for the Army, the use of plastic for brass in fuze M501, saving 192,500 pounds, the use of yellow brass for red brass in belt clip, saving 119,200 pounds, and the use of carbon steel for buckles and duffle bag fixture, saving 505,840 pounds; for the Navy, use of galvanized metals for copper in flashing, gutters and downspouts, saving 458,041 pounds. The Air Force reported quantitative savings only in connection with a scrap salvage program, yielding 3,197,702 pounds.

In the 129 completed projects, the principal substitution was of carbon steel usually with a galvanize or phosphate coating; 44 such projects were reported. In 24 projects, chrome stainless steel was used in place of brass. In 11 cases a plastic or reinforced plastic was used, and in 10 cases aluminum was used. Various less-critical alloys were used in 12 projects; powdered metal in 2. A redesign was undertaken in 22 projects and a process change in 3.

In the 76 projects still in progress at the close of the year, plastic or reinforced plastic was proposed for use in 18 projects, redesign in 16, steel in 14, chrome stainless in 3, and zinc in 2.

Chromium

Chromium is a metal used principally as an alloying additive in alloy steels, although it is sometimes used as a nonferrous alloy, as a metallic plating, and (in oxide form) as a refractory material. It comes mainly from Turkey and Africa; there are some low grade deposits of chrome ore in the United States.

Of all the principal alloying additives in high temperature applications, such as in turbojet engine components, chromium is least critical. In alloy steel applications, chromium is also in a favorable supply position surpassed only by vanadium. The chromium stockpile is in a strong and improving position.

Substantial progress has been made toward the achievement of the stockpile objective for metallurgical grade chromite as a result of Government activity. Some foreign sources now have a surplus available over existing demand. A very limited supply of domestic high grade material is being produced under Government subsidy, and a large contract for low grade domestic material is also in effect although the probable use for this supply is not now apparent. Gross transactions for metallurgical chromite amount to about $50 million, with ultimate cost to the Government estimated at about $27 million. The Government has also underwritten a $500,000 outlay for a geological survey of the resources of refractory grade chromite in Cuba. While Cuban ore is not now competitive with the Philippine supplies normally imported, the development of the Cuban ore body would make available an emergency source strategically located close to the United States. Refractory grade chrome is also being stockpiled.

Projects to conserve chromium that were completed in 1952 numbered 59, with savings of 1,879,227 pounds; active projects at the end of the year numbered 119. Although little emphasis was placed on the conservation of chromium in military applications during 1953, a considerable extent of conservation actually took place. The reason for this was that in austenitic stainless steel, chromium is used in conjunction with nickel; thus, conservation of chromium has been a by-product result of the energetic program of nickel conservation by the military departments. Similarly, the conservation of nickel and molybdenum in alloy steels through the use of boron or carbon steel substitutions, chromium is an incidental beneficiary.

Projects yielding major savings of chromium all involved primarily the savings of nickel. The Army completed two projects, one involving substitution of ferritic welding electrodes for stainless steel electrodes in the self-propelled 40 millimeter gun, twin, T–141, saving 48,906 pounds of chromium and another project to use ferritic electrodes in construction of the 105 millimeter howitzer, self-propelled, T–98, saving 29,260 pounds. The Navy completed 1 major project to substitute aluminum for austenitic stainless steel for 20 generator bases on nonmagnetic minesweepers, saving 54,000 pounds of chromium. The savings of 153,000 pounds by the Air Force was not identified as to project.

Among the 112 completed projects, in addition to the major projects mentioned above, there were 31 in which carbon steel was substituted for alloy steel, 9 in which boron steels were substituted for higher alloy steels, and 37 in which some substitute was found for austenitic stainless steel. The 37 were: chrome stainless, with lower percentage of chromium (15), plastic and reinforced plastic (7), carbon steel (6), aluminum (4), galvanized steel (2), and malleable iron casting, brass rod, and nylon-covered steel (1 each). Other conservation measures were: carbon steel for elimination of chromium plate, cast iron for chrome and sheet steel, drill rod for tool steel, reduced use of chrome refractory, standardization, process and/or design change, redesign, and salvage practice.

Among proposed or active projects, 11 propose substitution of carbon steel for alloy steel, 9 propose redesign, 6 the substitution of boron steels for steels with higher alloy content; substitutes for austenitic stainless steels include plastic and reinforced plastic (13), ceramic-coated carbon steel (4), aluminum (3), and magnesium (2).

Cobalt

Cobalt is a ferro-alloying metal somewhat similar in properties to nickel but less than one-tenth as abundant. It is produced principally as a byproduct of the copper and nickel mining industries. Its military uses include high temperature alloys, binder for tungsten carbide in machine tool cutting tips and armor-piercing projectiles, antierosion liner alloy for machinegun barrels, and magnetic alloys for electronic and other applications.

Before the Korean emergency most of United States-consumed cobalt was imported from the Belgian Congo, with additional supplies coming from Canada.

A small portion of United States requirements was domestically produced. During the Korean emergency large expansion of jet engine production was superimposed on a substantial new demand for magnetic alloys, and cobalt became very tight. Strenuous efforts to reduce jet engine requirements for cobalt have had marked success.

In 1950 supplies available to the United States approximated 10 million pounds of cobalt, almost all of which was required for military production and essential industrial and civilian requirements. An expansion goal of 18 million pounds per year by 1954 was established in January 1952, and raised twice during that year to a total of 27 million pounds by 1955. Contracts under the Defense Production Act expansion program and stockpile contracts have served materially to increase imports and domestic supply from 11 million pounds in 1951 to 20 million pounds in 1953. As a result, substantial acquisitions have been obtained for the stockpile.

Because of the degree of similarity in properties of cobalt to nickel, there is some extent of substitutionability between the two metals. Although cobalt is definitely improved in supply-demand position over 1950, its conservation and efficient utilization should continue to be emphasized.

In 1952, 7 projects to conserve cobalt were completed, yielding savings of 206,500 pounds. An additional 40 projects were reported as active at the close of the year.

Conservation programs in cobalt continued in 1953 at a reduced level, in response to the easing of requirements and improvement of supply. Although only 23 projects have been identified from military reports, it is certain that a substantial additional number of projects (e. g. those in the "miscellaneous materials" category dealing with high-temperature alloys or materials) in fact concern cobalt among other alloying additives. Moreover, progress by private industry in both production and fabrication methods of high-temperature materials is certain to have a favorable effect on the utilization of available cobalt.

One completed project to conserve cobalt concerns recovery of military scrap; all the rest deal with redesign of aircraft engines or research into alloys or fabrication of jet engine turbine buckets. Projects in progress deal with 4 broad engine studies, 3 projects to develop less critical alloys, the use of cements, powdered iron, or coated low-alloy, and 5 deal with engine redesign; 2 projects propose reduction of cobalt in cemented tungsten carbide shape, 1 project aims to substitute nickel for cobalt in electron tubes and 1 to recover and reuse magnets from magnetron tubes.

Feathers and down (waterfowl)

This material is essential in the production of sleeping bags and casualty-evacuation bags. Waterfowl feathers and down in the past were normally imported from China. No other material approaches the combination of insulation, light weight, compressibility, elasticity (filling power), and launderability possessed by waterfowl feathers and down.

The foreign assets control regulations of the Treasury Department prohibit United States imports of Chinese origin, thereby eliminating the principal source of supply of this strategic and critical material required for military sleeping bags, casualty-evacuation bags, and medical pillows. Feathers and down are also being stockpiled. Domestic production is small and is strictly a byproduct of ducks produced for food. Since meeting the existing stockpile objective will be difficult with China eliminated as a source of supply, attention is being focused on basic research programs directed toward the development of acceptable substitute materials.

Although no military projects were reported under the conservation program in either 1952 or 1953, it is understood that several such projects exist. The most promising substitute at present appears to be modified or treated chicken feathers. Selected chicken feathers (readily obtainable in the United States) can be treated with reasonable permanence to enhance their filling power and insulation qualities. As an extender they can be used up to 25 percent in admixtures with 45 percent waterfowl feathers and 30 percent down in sleeping bags and casualty-evacuation bags.

Columbium

Columbium and tantalum are two metals essential to defense and also included among the materials being stockpiled. The Government's purchase program, involving over $86 million in borrowing authority to expand supplies of these 2 metals, has resulted in sharp increases in imports which provide 99 percent

of supply. Columbite concentrates imported into the United States increased from 1.5 million pounds in 1951 to 1.9 million in 1952 and 4.2 million in 1953. The columbium-tantalum metal content of these concentrates went from 800,000 pounds in 1951 to 2.1 million pounds in 1953. Imports of tantalite concentrates increased from 238,000 pounds in 1951 to 752,000 pounds in 1953. Efforts to develop domestic production of columbite-tantalite have uncovered a potential source which could furnish about one-fifth of the annual domestic industrial requirement for columbium.

Columbium is a minor ferroalloying additive, sparsely occuring in nature, and important chiefly as a corrosion-resistant stabilizer in austenitic stainless steel and as a strengthening element in high-temperature alloys. It is largely imported from Africa. The large expansion in requirements for stabilized stainless steels for jet aircraft manufacture early in the Korean emergency, created a serious shortage situation. Moreover, stockpiling of columbium had lagged. In response to this situation, aggressive programs to expand production of columbium, and to conserve its use, were entered upon. At present, military requirements for columbium appear to have been reduced, supply is expanded, and the stockpile position is quite favorable.

The military departments reported for 1952 that they had completed 15 projects to conserve columbium; another 31 were in development. Reported savings of columbium in that year were estimated at 119,101 pounds.

The principal substitution device followed in reducing requirements for columbium is by the addition of ferrotitanium to stabilize austenitic stainless steels. Other methods of conservation include: ceramic coating to protect heated engine parts, development of improved designs, improved fabrication techniques, and control procedures to prevent unnecessary uses and to insure full utilization of scrap metal containing columbium. The consequence of these measures, some of which have been continuously in application since the middle of the Korean war, is to ease the supply-demand situation in columbium, so that the priority of conservation action in this material has been reduced.

Asbestos (chrysotile)

Asbestos is a fibrous mineral. Chrysotile asbestos is the principle type used in the spinning of fabrics. It comes mainly from sources in Africa and Canada. A shortage in supply (both currently and under mobilization) exists in certain grades of this material. In these grades, the spinnable nonferrous fiber, stockpile procurement is moving slowly.

For the spinnable nonferrous grades of chrysotile there is no satisfactory or complete substitute in certain dielectric insulation in military items. There should be continued emphasis on conservation and substitution measures in these grades. However, the supply of ferrous spinnable grades (grade 3 and above) of chrysotile is favorable and expansion of production in the Western Hemisphere is taking place. There need be no emphasis upon reduction in military uses of these ferrous grades.

Although chrysotile asbestos has been on the list of strategic and cricital materials for stockpiling for many years, little progress has been made toward the completion of the objective. For this reason the Government has undertaken a program to expand both domestic and foreign production of strategic grades. Domestically, the program provides for a purchasing depot at Globe, Ariz., where the Government is committed to accept up to 1,500 short tons of certain grades of asbestos. Up to June 30, 1954, 451 tons of stockpile grade were thus procured. To stimulate foreign production the Government has entered into a purchase contract with a firm in Venezuela under which a minimum of 2,300 tons and a maximum of 3,500 tons may be delivered by the end of 1958.

No projects to conserve chrysotile asbestos were reported in 1952. Two projects were reported, both by the Navy, in 1953. Both were completed. One project involved changed design of electric shipboard cable; the other a plastic sealer. No estimate of savings was reported for the first but a savings of 15,000 pounds of asbestos and a 15 percent reduction in cost was reported for the second project.

Diamonds, industrial

The stockpile position for industrial stones is adequate; however, for crushing bort, the stockpile position is only fair and it is necessary to intensify emphasis on conservation of diamonds in this form.

Only one project for conservation of industrial diamond bort was reported in 1952. This was a project, in study status, by the Navy for an application involving arc-machining.

Five projects were reported for 1953 to conserve diamonds, of which 3 were completed and 2 were under development at the close of the year. In the completed projects (all by the Navy), 2 involved design changes which eliminate the need for diamond dies in production of electronic equipment, and 1 concerned reclamation of diamond particles from diamond grinding wheels in military shops. The 2 projects under development (1 each by Navy and Air Force) involve arc-machining and ultrasonic grinding processes. No estimates were made of the savings from completed projects.

Beryllium

Principal industrial use of this metal is as a hardener of copper-base alloys. It is sparse in occurrence and is mostly imported from Brazil and Africa. During the Korean emergency supplies of the ore were not readily available and conservation was stressed. Since then, the availability of both current imports and reserve stocks has greatly improved and, in addition, several methods have been found acceptable for eliminating or extending the use of beryllium. Accordingly, while it still remains on the Department of Defense materials conservation list, the priority of need to conserve it is very much reduced in terms of mobilization readiness.

Beryl is one of the materials being stockpiled. The General Services Administration is maintaining beryl (beryllium ore) purchase depots at Franklin, N. H.; Spruce Pine, N. C.; and Custer, S. Dak., in a program initiated under the Defense Production Act. It is estimated that more than 400 tons of beryl will be delivered under this program by June 30, 1957. Beryl is being purchased currently for the stockpile and is eligible for procurement, also for the stockpile, by barter of surplus agricultural commodities.

Completed projects in 1952 to conserve beryllium numbered 5, with savings of 547 pounds reported; an additional 6 projects were underway at the end of the year. Projects completed in 1953 numbered 5, with only token savings reported; 2 additional projects were in progress. Major savings from the uncompleted projects concern the substitution of aluminum bronze for beryllium copper in spark-resistant hand tools and substitution of carbon steel for beryllium copper or alloy steel in 75 millimeter shell fuze.

Mica (muscovite)

Muscovite mica is a crystalline nonmetallic mineral used in electronic applications because it is a good nonconductor of electricity and can be split into thin sheets. It is mainly imported from India. During the last several years considerable interest has been expressed by the military departments in the development or testing of possible substitute or alternate materials for muscovite mica. A report by the National Academy of Sciences, August 27, 1952, recommended four broad lines of investigation be pursued, and suggested that it was apparently feasible to develop acceptable materials available domestically to replace imported mica.

In addition to the various efforts undertaken to conserve strategic mica in electronic tubes and electrical insulation, as well as vitreous enamel, glass, and teflon in capacitors, the Government has initiated an expansion program for both domestic and foreign mica production under the authority of the Defense Production Act of 1950, as amended. While not all mica produced under this program will meet stockpile specifications, so far approximately 50 tons of domestically produced mica have been accepted for the stockpile out of a probable total eventual yield of 350 tons of stockpile grade, and approximately 350 tons of foreign mica have been accepted out of a probable total eventual yield of 1,250 tons of stockpile grade.

There were 6 programs underway in 1952 to conserve muscovite mica, all by the Navy, of which 1 was completed, saving 1,600 pounds. These programs dealt with redesign, use of mica paper reconstituted from domestic mica, the use of glass, synthetic spacer material (terratex), and investigation of a British plastic. In 1953 there were 9 projects, all under development, 2 by the Army and 7 by the Navy. In 2 projects it was proposed to design out the use of mica, 1 project concerned research under a general contract dealing with tube spacers and capacitors, and others concerned development of such substitutes as glass-bonded synthetic mica, mica paper, terratex, reconstituted mica, and glass.

Army Signal Corps has completed a contract with the University of Michigan for studies of several varieties of natural micas. This work will be of great value to those working on the development of synthetic mica sheets.

Navy Bureau of Ships has contacts with Brush Beryllium Co. and the Bureau of Mines Electrotechnical Laboratory on synthetic mica.

Industry is now producing 3 tons of synthetic mica per week, which is primarily being used for molding glass-bonded, synthetic mica radio insulating material. Evaluation tests by Mycalex Corp. indicate that glass-bonded, synthetic mica can fully meet the requirements of JAN–I–10, grade L–5A on insulating materials, ceramic, radio, class L. The material can be compression or injection molded as well as machined into intricate shapes. The Mycalex Corp. is now producing a coil at a price competitive with ceramic.

Mica paper using a domestic low-grade mica has been developed and is now commercially available. It will replace pasted mica from scarce imported mica in numerous applications.

Navy Bureau of Ordnance has a contract with Corning Glass Co. to develop production techniques for high-power transmitting capacitors using glass as a dielectric. Use of glass is expected to reduce the requirements for high-grade mica by 50 to 60 percent.

In addition to the various efforts undertaken to conserve strategic mica through the use of substitutes such as treated paper and lower quality mica in electronic tubes and electrical insulation, as well as vitreous enamel, glass, and teflon in capacitors, the Government has initiated an expansion program for both domestic and foreign mica production under the authority of the Defense Production Act of 1950, as amended. While not all mica produced under this program will meet stockpile specifications, so far approximately 50 tons of domestically produced mica have been accepted for the stockpile out of a probable total eventual yield of 350 tons of stockpile grade, and approximately 350 tons of foreign mica have been accepted out of a probable total eventual yield of 1,250 tons of stockpile grade.

Aluminum

United States production of primary aluminum has been doubled from the pre-Korean level of about 700,000 short tons a year to a present level of about 1,500,000 tons a year. To encourage this expansion commitments of over $1,100,000 under the Defense Production Act have been entered into, guaranteeing markets to the producers in the event that their output cannot be sold elsewhere. In addition, aluminum is one of the materials being stockpiled.

Silk

The United States is wholly dependent on the Eastern Hemisphere for new supplies of silk which is used by the military services for thread, surgical sutures, cartridge cloth, and igniter pads. Silk has especially desirable properties for cartridge cloth in that it resists corrosive effects of nitrates, has good strength, and leaves no combustible residue in gun barrels to cause premature ignition of subsequent charges. In sutures, silk lends itself to tying a firm knot and the material is absorbed by the tissues when left in the body after an operation.

An objective for silk has been established in the national stockpile, to cover minimum essentials in a war emergency, and progress is being made toward this objective. However, the stockpile objective takes into account requirements for only a very small portion of the cartridge cloth needed for ordnance.

Army Ordnance, as a result of their aggressive research on the problem of finding suitable alternate materials to silk for cartridge cloth and igniter pads, considers that they are now completely independent of silk except for the vary largest calibers. Their investigations indicate that acetylated cotton, orlon, acrylan, and direct-spun high-tenacity rayon are all fully acceptable for all except the aforementioned largest caliber shells. Their continuing research to develop replacements for silk in the large calibers is promising.

Navy Bureau of Ordnance is investigating substitutes for silk in cartridge cloth having required characteristics of strength, rapid and complete burning, and good storage life. They have investigated wool and rayon mixtures. Tests are being made on orlon and acetylated cotton. Other promising materials will continue to be evaluated.

Although requirements of silk for cartridge cloth for powder bags and igniter pads have been largely eliminated through the development and acceptance of substitute materials, a small percentage of these requirements still remains for which the physical and chemical properties of silk are considered necessary. Consequently, silk is among the materials being stockpiled. However, research programs for the development of acceptable substitute materials for this segment of requirements are being continued.

Rubber (crude natural)

World supply of natural and synthetic rubber more than meets current world requirements and the national stockpile goal (including a contingency reserve) has virtually been met. Further military efforts to conserve natural rubber deserve priority chiefly from the standpoint of the economy to be achieved by reducing stockpile requirements, rather than to overcome any supply deficiency during mobilization. Nevertheless, it is important that military consumers of rubber hold the line and not revert to larger percentages of natural rubber. The domestic synthetic industry requires support to preserve its capacity and technological ability. The national stockpile objective, moreover, was based on the concept that maximum possible percentages of synthetic rubber would be used in tires and tubes. Major portions of natural rubber would be reserved, under mobilization, for large truck tires and for aircraft tires and tubes.

The military departments reported 27 projects to conserve rubber in 1952. Ten completed projects yielded savings of some 2,720,600 pounds of rubber and 17 projects remained active at the close of the year.

Projects in 1953 included six completed (Army 2, Navy 1, Air Force 3) with 11 active at the close of the year (Navy 4, Air Force 7). Completed projects saved rubber by elimination of part, redesign, substitution of nylon, development of aircraft antiskid devices, and development of a retreading process for aircraft tires.

Projects in development include preservation of rubber on ship bearings, development of tubeless tires for aircraft, increased use of synthetic rubber in aircraft parts, aircraft personnel equipment, and piping, and improved procedures and equipment for aircraft tire wear analysis.

Both of the two major objectives of the Department of Defense research and development program on rubber contribute toward the conservation of natural rubber. The greatest research and development emphasis is directed toward obtaining synthetic rubbers superior to natural rubber in performance under such conditions as exposure to extreme heat and cold, resistance to gasoline and oil. Indirectly, success in the accomplishment of this objective may reduce the demand for natural rubber. The other important objective is to reduce military dependence on the natural rubber stockpile, particularly for heavy-duty tires. To a great extent the DOD relies upon the Office of Synthetic Rubber research program for the more basic research in this field.

Quartz, crystal

This material became short in World War II, because of the great expansion in the production of all kinds of electronic equipment. As suitable grades of quartz are imported almost entirely from Brazil, the material was placed on the stockpile list and an objective was established for an adequate reserve. Since then, the reserve has been met and an additional contingency reserve has been accumulated. As a result, military measures to conserve radio-grade quartz crystal should be assigned no priority as far as materials conservation objectives are concerned.

Projects to conserve crystal quartz, reported in 1952, numbered five. One completed project yielded savings of 50,000 pounds, and four projects were active at the close of the year. There were 4 projects in development in 1953, 1 by the Army and 3 by the Air Force. The Army project is a joint one with the Air Force to synthesize quartz crystal of radio grade. The other two Air Force projects propose development of non-crystal oscillators and crystal-saving circuits.

Wool, apparel

During the Korean emergency, wool consumption rose considerably, such that reserves of wool in the inventory of the Commodity Credit Corporation were exhausted. The prospect of a wool shortage appeared to be at hand as the price of apparel wool rose rapidly. In response, the military services undertook programs to introduce admixtures of synthetic fibers into uniform cloth and other fabrics. Subsequently, a war reserve of 100 million pounds (clean basis) of military fabric and end items was established.

Since then, the supply-demand situation for wool has greatly improved. The Commodity Credit Corporation, under its price support program, has acquired over 100 million pounds of wool (grease basis) and the prospect of future mobilization deficit is not a likely one. Under these circumstances, military programs to conserve wool deserve reduced priority.

Wool is not among the materials being stockpiled under the Stockpile Act. The Department of Agriculture is currently administering various programs designed to aid and encourage the domestic production of wool.

The Army is conducting studies to determine the minimum wool grade requirements for each standard Army fabric. Permitting larger percentages of coarse fibers will result in a more effective use of the domestic wool supply. It has been determined that the weight of the 18-ounce serge formerly used for the uniforms for general wear could be reduced to 16 ounces without affecting the overall comfort and warmth characteristics, with an improvement in appearance resulting from the use of less bulky and less stiff material. It has been found possible to use reprocessed or reused wool in place of new wool in blankets and in lining materials. Blends of wool with such synthetic fibers as nylon, dacron, orlon, and dynel are being investigated for use as alternate for 16-ounce felted wool shirting (a major procurement item) and in tropical worsted type fabrics for officers' summer uniforms.

The Navy is investigating blends of synthetic fibers such as viscose, acetate, nylon, orlon, dacron, and dynel with wool in enlisted men's blue jumpers and trousers. They are also evaluating a 22-ounce wool fabric as a replacement for 30-ounce jersey used in enlisted men's overcoats. A knitted wool blanket which has greater thickness, much less weight, higher resiliency, and more dimensional stability than standard type I Navy crew blankets, has been developed and is being evaluated. In addition, this blanket has lower production costs, faster production, is independent of natural fibers, and provides greater warmth with less weight. They are evaluating 100 percent dacron and blends thereof with wool, and viscose for use in officers' tropical uniforms. The Navy is also investigating the fundamentals of blending fibers.

The Air Force has completed investigations of blends of wool with various synthetic fibers, with the result that specifications are being revised to permit the use of a blend of 70 percent wool with 30 percent synthetic fiber as an alternate to 100 percent wool in velour overcoats and serge blouses. A nylon liner has been developed as a substitute for wool liners in Air Force cold-weather clothing.

Cadmium

Cadmium is a soft corrosion-resistant metal used mainly for electroplating. The United States is the major world producer of this metal, as a byproduct of the zinc mining industry. Because it is a byproduct material, cadmium is rather inflexible in supply and is not capable of any extensive expansion in supply to meet the special requirements of mobilization. Early in the Korean war, the widespread use of cadmium plating caused the metal to be short and conservation measures became necessary. Subsequently the supply-demand situation eased and the full stockpile objective has been readily completed.

Because of the "sensitivity" of cadmium it needs to be especially closely watched. The occasional interest of the military departments in nickel-cadmium storage batteries is a case in point. Minor use of cadmium for this purpose might yield economies but any substantial plans for this application would create a serious shortage problem for mobilization. On the other hand, for most plating applications cadmium and zinc are readily interchangeable. For this reason, as well as the fact that the stockpile objective is completed, the conservation of cadmium has received and should receive only a low priority.

The Army completed 5 projects in 1953, saving 1,497 pounds of cadmium. The Air Force completed 1 project and the Navy and Air Force each had 1 active project at the close of the year.

The only significant completed project to conserve cadmium was the elimination by the Army of a requirement for cadmium plating on a tank part, saving 1,188 pounds. There were 3 completed projects of similar nature and 2 additional projects to substitute phosphate coating for cadmium. The 2 active projects concerned printed electronic circuitry (saving cadmium-bearing solder) and research in electroplating. In 1952, there were 3 completed projects and 4 in progress; savings in that year were estimated at 10,000 pounds.

Titanium

Titanium has come to assume considerable importance as a light, strong, corrosion-resistant metal. This metal combines many of the valuable structural features of aluminum and steel with certain characteristics that are superior to either. It offers great promise as an improvement over both in certain aircraft, missile, and ordnance uses. Titanium ores are relatively plentiful.

It required a great amount of science and technology, however, to produce useful metallic shapes and parts from the raw materials. We believe that the successful development and engineering application of titanium in this country will represent a major technological breakthrough. It opens up the possibility of military designs with performance characteristics which would be impossible of attainment with other known materials and could have an important bearing on the outcome of our technological race.

The Government has entered into contracts intended to stimulate production and use of titanium by providing for Government support of sponge production. For the past year and a half the use of titanium has been at only about one-fifteenth the rate established by these guaranties. Most of the current supply has gone into experimental applications and very few production applications have so far been made. This is due in part to the limited production quantities that have been available and to the lack of knowledge in the art of applying the metal.

As titanium in this development phase is about as dear as silver, these Government contracts will build up titanium production to something like a billion-dollar annual program. In the face of this, we have been much concerned about the lagging application. Recently two steps have been taken to bolster this situation. We have established in the Defense Department a Steering Group on Titanium Research and Development, which is broadly representative of the various departments and offices having an interest in the program. This group is given the responsibility for formulating broad policies and plans to guide the efforts of the Army, Navy and Air Force and their contractors along lines to achieve the quickest and soundest results; in other words, to exploit to the maximum the strategic values of this new material.

The second step in the new attack on titanium is complementary to the first and is perhaps of more direct interest to industry. The lack of know-how in use of the new metal, and the technical difficulties, both major and minor, which have cropped up have pointed out the need for a customer service laboratory specializing in titanium metallurgy.

After considerable deliberation it has been decided to establish such a service laboratory at Battelle Memorial Institute in Columbus under Defense Department sponsorship. This laboratory will undertake to provide consulting services to defense industry on all phases of production of the metal and its application. It will conduct short-range investigations as required to assist fabricators in the use of the metal. It will act as a clearinghouse for information resulting from Government-sponsored work in other laboratories, as well as for as much information on the results of industry-sponsored work as the individual companies are willing to disclose.

It is not intended by this step to concentrate the titanium metallurgy program in one laboratory. The major tasks of the research and development effort will, as previously, be sponsored by the individual agencies of the Defense Department in laboratories of their own choice, and much work along this line will continue to be done by the industry on its own account.

It is believed however that a highly competent technical outfit, as it becomes familiar with all phases of the titanium effort, will be of great value in pointing out the deficiencies of our defense program on titanium. Its advice will assist in that most difficult task of research and development management; namely, the identification of major problem areas, assessing the relative importance of the various problems, and helping us to direct the effort accordingly.

(Whereupon, at 1:37 p. m., a recess was taken until 3 p. m., of the same day.)

(The following was subsequently submitted for the record:)

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE,
RESEARCH AND DEVELOPMENT,
Washington 25, D. C., March 11, 1955.

Mr. JEROME S. ADLERMAN,
Counsel, Minerals, Materials and Fuels, Economics Subcommittee,
United States Senate.

DEAR MR. ADLERMAN: In accordance with Senator Malone's request during my recent appearance before the Special Subcommittee on Minerals, Materials, and Fuels Economics, I am furnishing below some additional information on a number of subjects:

The Senator requested a statement of the persons through whose hands analyses of quantitative requirements of titanium pass before being furnished to the Office of Defense Mobilization. Most of the titanium during the next few years is expected to be used in the aircraft industry. Forecasts of use are secured from the industry by the Aircraft Production Resources Agency which is a joint Navy and Air Force Establishment managed by the Air Materiel Command at Wright-Patterson Air Force Base, Dayton, Ohio. Col. T. B. Ardis is in charge of this activity. The figures for Air Force requirements are submitted through Col. Carl Monroe, head of the Industrial Resources Division, Air Materiel Command, to the Directorate of Industrial Resources, Headquarters, United States Air Force. Col. W. R. Carter is the present Director of Industrial Resources. The Director of Industrial Resources, USAF, furnishes the figures to Mr. Roger Lewis, Assistant Secretary of the Air Force (Material), who forwards them to the Office of Assistant Secretary of Defense (Supply and Logistics), Mr. T. P. Pike. The figures for Navy requirements are compiled by Capt. H. S. Dodge, USN, of the staff of the Bureau of Aeronautics representative, central district, and submitted to the Bureau of Aeronautics, Department of the Navy. Data for current requirements are handled by the Production Division, and mobilization requirements by the Industrial Planning Division of the Bureau of Aeronautics. The current director of the former division is Capt. F. D. Pfotenbauer, and the current director of the latter division is Capt. F. Cutter. The current and mobilization requirements are then forwarded to the Production Division of the Office of Naval Material. Capt. E. T. Aldridge is the current director of the Production Division, Office of Naval Material. These figures are received in the Office of the Assistant Secretary of Defense (Supply and Logistics) by Dr. T. C. May of the materials section and pass from him through the hands of Mr. Carl Rolle, head of the materials section, Mr. Frank X. Brown, Staff Director, Requirements Review and Analysis, Mr. John Hamlin, Acting Director of Planning and Review, and Mr. Pike, by whom the information is transmitted to the Office of Defense Mobilization.

The Senator requested further information on the extent to which substitutes are available for certain critical electronic materials, namely, quartz crystals, selenium, block talc, germanium, and mica.

Research and development programs for the production of synthetic quartz have progressed to the stage where a substitute for natural quartz has been achieved. However, such programs must receive continued support in order to improve production capability and to reduce present production costs. Accordingly, available natural quartz will continue to be used in the construction of military electronic equipment during the immediate future.

Selenium finds its primary military use in rectifiers where it is used both in electronic equipment and electric-power applications. Substitutes are available for all of these uses, selenium being preferred, however, in many applications, either because it is more economical or smaller in size for the same capacity, or both, to alternative rectifiers. The chief alternative rectifiers used in one or another of the applications where selenium is preferred are motor generators, vacuum tubes, copper oxide, or germanium. (Other rectifiers under development use titanium or silicon.) In general, the available alternative rectifiers, except germanium, are larger and heavier for the same capacity, and germanium is more expensive. Germanium is also somewhat scarce, so that it is questionable whether it could be widely substituted for selenium without creating a critical shortage in germanium.

There are two schools of thought with respect to the essentiality of block talc. Although the Materials Advisory Board made an extensive study of the need for block talc, it was not possible to wholly reconcile the different opinions. One view is that there are a number of substitutes which are wholly adequate, and it is, therefore, unnecessary to stockpile block talc. The other view is that for certain special types of electronic tubes which, although they have important military uses, are produced in only small quantities there is no material as useful as block talc for the spacers used to keep the elements in proper relationship. My own view, based on this study, is that the use of block talc is probably more a matter of custom than necessity.

Germanium is primarily used in transistors (which are used in place of electronic tubes) and in power rectifiers. Germanium transistors seem to have several inherent limitations for use in military electronic equipment, including sensitivity to heat and moisture. Silicon transistors, which seem to be more adaptable to extreme environments, show promise as a substitute for germanium. However, neither germanium nor silicon transistors are wholly satisfactory in

their present state of development. As mentioned above, germanium can be used in place of selenium for power rectification. In such use a germanium rectifier is only a small fraction of the size of a selenium rectifier for the same power rating, but the germanium is more expensive, and there may not be sufficient germanium available at a reasonable price to permit widespread use as a substitute for selenium.

A great many substitutes for mica as dielectric materials in capacitors are used, but for applications requiring the smallest possible size and resistance to high temperatures there is as yet no fully adequate substitute for natural mica.

The Senator desired to have further information on the availability of substitutes for industrial diamonds. He also wished to have the names of the members constituting the Materials Advisory Board panel which prepared the reports on New Processes for Machining and Grinding and the Second Report on New Processes for Machining and Grinding. There are attached copies of these two reports, which contain the names of the panel members and also the most complete information we have on the practicability of substitute grinding methods. These reports deal primarily with grinding requirements of industrial establishments. There are certain other needs, such as oil-well drilling, where the substitution methods are not applicable and natural diamonds are required. In this connection, you may have seen the recent announcement by the General Electric Co. that they have succeeded in synthesizing true diamonds and that they expect to be able to manufacture them at a cost lower than the present price of industrial stones.

Sincerely,

JOHN H. GARRETT,
Secretary, Technical Advisory Panel on Materials.

Report No. MAB–18–M
Copy No. 13

REPORT BY PANEL ON NEW PROCESSES FOR MACHINING AND GRINDING OF THE MINERALS AND METALS ADVISORY BOARD

NEW PROCESSES FOR MACHINING AND GRINDING

This report prepared and submitted to the Chairman of the Research and Development Board under Contract DA–49–025–sc–83, between the Department of Defense and the National Academy of Sciences.

Division of Engineering and Industrial Research, Division of Geology and Geography, National Academy of Sciences, National Research Council, Washington 25, D. C., January 18, 1952.

NATIONAL ACADEMY OF SCIENCES,
NATIONAL RESEARCH COUNCIL,
METALLURGICAL ADVISORY BOARD,
Washington 25, D. C., February 6, 1952.

DEAR SIR: I am forwarding to you herewith a report on new processes for machining and grinding which has been submitted through the National Academy of Sciences, National Research Council to the Chairman of the Research and Development Board. The contents, conclusions, and recommendations are solely those of the Minerals and Metals Advisory Board and its panel and staff on new processes for machining and grinding.

Very truly yours,

FRANCIS C. FRARY,
Chairman, Minerals and Metals Advisory Board.

PREFACE

The Minerals and Metals Advisory Board, through the National Research Council is distributing this report of the panel on new processes for machining and grinding to those agencies and individuals who have contributed to, or who will be concerned with the subject matter. This report is a report under contract DA–49–025–sc–83 between the Department of Defense and the National Research Council, which was negotiated at the request of the Research and Development Board.

For immediate release, this panel report is unclassified and is offered for information. If publications use information contained in the report, they should not show any panel authorship, but credit may be given to the Minerals

and Metals Advisory Board of the National Research Council. The appendixes may be published only with the express permission of the authors.

The distribution of this report is as follows:

Copies 1 and 2. Mr. Walter G. Whitman, Chairman, Research and Development Board.

Copy No. 3. Dr. D. W. Bronk, President, National Academy of Sciences.

Copy No. 4. Prof. C. R. Soderberg, Chairman, Division of Engineering and Industrial Research.

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SUMMARY

The potential values of new processes for machining and grinding have been evaluated with the conservation of diamond bort being of special interest. Some of these new processes appear promising as methods for conserving diamond bort when grinding sintered carbides; and they appear to offer promise for forming and finishing other hard-to-machine materials besides carbides. The electromechanical and electrochemical types of processes are limited to shaping and finishing electrically conducting bodies such as metals and carbides. Abra-

sive types of methods, including diamond wheel grinding and ultrasonics, are capable of cutting all hard materials.

Eight specific important operations, where new processes for machining and grinding may be needed, have been emphasized in this report. For each of these operations, at least one of the new processes appears to offer possibilities for satisfactorily doing the job; and for shaping and finishing dies, two of the processes are in commercial use. Most of the diamond bort is consumed in shaping, finishing, and sharpening cemented carbide tools, such as single-point tools, milling cutters, and dies.

Except for shaping and finishing dies, none of the new processes are in actual commercial use; nor are there fully proven designs available for immediate use in manufacturing machines to meet a shop demand toward saving bort. However, there are machine designs available for practical evaluation of these processes and of the results of using them to shape or sharpen materials and tools. A limited number of machines is becoming available for practical evaluation. Before substantial savings of diamond bort can be realized, there must be thousands of commercially operable units based on one or more of the new processes. At the present stage of development, some of the processes appear capable of using existing machine units without extensive modification.

Most of the new processes considered are worthy of more intensified research and development, leading as rapidly as possible to large-scale industrial testing. For essentially every application, it will be necessary to carry out performance tests under conditions of shop operation, not only on the new cutting machines, but also on the as-shaped or as-finished items. Concurrent with performance tests, research and development on machine improvements and on fundamentals should proceed in a more intensified manner.

To assist in pointing out the direction of effort for making these new processes commercially available as soon as possible, four recommendations have been formulated. These recommendations are concerned with: (*a*) The military's activity; (*b*) industrial research and development; (*c*) an educational program; and (*d*) means of obtaining effective liaison and coordination.

1. INTRODUCTION

Diamond wheel grinding has for some time been the only practical method for shaping and finishing cemented carbide tools and tungsten carbide projectile cores. These job items account for approximately 70 percent of the diamond bort consumption in this country. At the present time, imports and reclamation of diamond bort are limited and although there may be some increase, these might not be sufficient to produce the tools and military end items in the event of a substantially increased preparedness or mobilization program.[1] In addition, many new military items, which involve hard-to-machine materials, are being developed, and the anticipated rate of production of these is very large. This will make the diamond bort procurement situation even more serious.

Therefore, there is a need for the development of new processes that do not require diamond bort. The basic phenomena of several such processes are known, but their status with respect to specific important applications must be evaluated. Descriptions of these new techniques and evaluation of their potential values with respect to these important operations or job items is the subject of this report. Also, some conclusions have been reached on the direction of research and development to bring these processes as rapidly as possible into large-scale industrial testing and use. These conclusions are based on understandings resulting from a panel meeting held on December 12 and 13, 1951, in Washington, D. C. Members of this panel included scientific and technical specialists in the fields of grinding, machining, electrochemistry, and cemented carbides.

2. DESCRIPTION OF NEW PROCESSES

Excluding various ramifications of methods employing bonded or coated abrasives, there are known to be several processes under development in this country which might be substitute methods for diamond wheel grinding operations or have possibilities for machining and grinding hard-to-machine materials that are badly needed for our preparedness program. These techniques include (1) the electrolytic process, (2) the electrosparking process, (3) the electroarcing

[1] See appendix II, The Diamond Bort Supply Problem.

process, (4) the ultrasonic process, and (5) various combinations of the preceding four.

The following summarizes the essential descriptions and features of each of the processes, as currently practiced or being developed in the United States.[2]

2.1. The electrolytic process[3]

Electrolytic grinding is usually performed by a revolving metal disc cathode in close proximity to an anodic workpiece while an electrolyte is applied to the disc and workpiece in the same manner as a coolant is applied to a grinding wheel and work. The method is usable for removing stock from electrically conducting bodies such as metals or metal carbides. It appears especially suited for removing stock from large surfaces, but its applications are limited where very small surfaces need be ground or for drilling of small diameter deep holes.

The electrolytic process utilizes steady direct current and a highly conducting electrolyte. Relatively low voltages of less than 25 volts and usually between 16 and 18 volts are used. It is characterized by low local heating and essentially no consumption of the cathode. In this process a true electrochemical action takes place in accordance with Faraday's law. With fixed current density, the rate of stock removal, in terms of volume per unit of time, is proportional to the effective area of the work exposed to the electrolytic action. Cathode-anode spacing and polarization effects appear to be critical factors in the electrolytic process, particularly for shaping or finishing cemented carbides.

2.2. The electrosparking process[4]

In the electrosparking method, stock is usually removed by making the work one of the electrodes in a properly designed circuit. Rapidly pulsed current (usually oscillatory) of the spark-discharge type is passed between the work and the other electrode in a dielectric fluid. The method is used for removing stock from electrically conducting bodies such as metals or metal carbides and is especially suited for forming small diameter, deep holes of any shape.

The electrosparking process is characterized by relatively high electrode consumption. Local heating is not experienced under ideal operating conditions. The range of voltage usually employed is between 40 and 300 volts. In a pure electrosparking process the electrodischarge is initiated by the voltage across the dielectric. The process is electromechanical and not electrochemical (as the electrolytic process). The stock is removed by a sparking action and the metal or metal carbide particles are carried away suspended in the dielectric fluid.

2.3. The electroarcing process

Cutting by the electroarcing process is performed by making the work anode with an arc maintained between the work and the cathode. The method usually utilizes pulsating direct current using a moderately conducting electrolyte such as water-glass solution. It is especially suitable for rapid cutoffs of hard metals and carbides and may be faster than existing cutoff procedures. However, in a pure electroarcing process, somewhat rough finishes are obtained.

In the electroarcing process, low voltages of less than 25 volts are usually used. For a pure electroarcing process the electrodischarge is initiated by contacting the electrodes and current is carried by vaporized metal ions. The process is commonly characterized by the deposition of some nonconducting film (such as silica) on the work and high local heating is evidenced with moderate consumption of the cathode. As is the electrosparking method, electroarcing is essentially electromechanical in nature, in that the metal or metal carbide is not removed by an electrochemical reaction.

2.4. The ultrasonic process[5]

As differentiated from the electroprocesses described above, the ultrasonic process does not utilize electric current directly for stock removal. Cutting or stock removal is accomplished by abrasive action at high frequency and low amplitude. Unlike the electroprocesses, the ultrasonic technique grinds nonmetal or nonelectrically conducting bodies as well as electrically conducting materials.

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[2] Similar processes are being developed in foreign countries. See appendix V, European Activities on Electroprocesses for Machining and Grinding.
[3] See appendix VI, The Electrolytic Process for Shaping Metals and Metal Carbides.
[4] See appendix VII, Electrosparking Process for Shaping Carbides.
[5] See appendix VIII, Ultrasonic Grinding and Machining of Both Metals and Nonmetals.

In the ultrasonic process, the cutting or grinding tool is usually vibrated in the frequency range from 16,000 to 29,000 cycles per second through an amplitude of not more than a few thousandths of an inch. The abrasive, which is usually 280-grit boron carbide, is carried in water to the tool and work. Other grit sizes and abrasive compounds, such as aluminum oxide and silicon carbide, may be used but these do not last so long as boron carbide. Consumption of the tool occurs during grinding and machining.

2.5. Combination processes

In addition to the four processes described above, machines may be devised for effecting combinations of some of these four processes. For example, the combination of the electrolytic and diamond-wheel grinding has been tested and is being developed. For this combination process, a metal bonded diamond wheel must be used for the cathode. The diamond particles act as insulating spacers, separating the work from the wheel, and as scrapers.

Machines have been tested and are being designed for effecting machining and grinding by electrolytic and/or electroarcing actions. The same electrolyte or more than one electrolyte might be used by the same equipment which will serve for either the electroarcing or the electrolytic process.

Tabulation of important machining and grinding operations and estimated applicability of methods

Job item or operation	Percent use of diamond bort [2]	Applicability of methods [1]				
		Diamond wheel grinding	Electrolytic	Electrosparking	Electroarcing	Ultrasonic
1. Sharpening of single-point tools	30	A	B	[3] B	C	[3] B
2. Grinding single-point tool chip breakers	20	A	B	B	C	B
3. Sharpening milling cutters and broaches	15	A	B	B	C	B
4. Grinding projectile cores	5	A	B	B	C	B
5. Shaping and finishing dies	4	A	D	A	D	A
6. Forming of turbine bucket attachments	----	B	B	B	C	B
7. Rifling of gun barrels	----	B	C	B	C	B
8. Machining and grinding of compressor discs	----	B	B	B	C	B

[1] A—In use on production scale. B—Appears applicable; promising but limited experimental data to date. C—Questionable applicability; not promising but might be developed to be promising. D—Limited applicability or not applicable; not usable in present state of development.

[2] Approximate percentage of total diamond bort currently being consumed in the United States. All diamond wheel grinding consumes about 85 percent of the bort and the operations considered account for 75 percent of the bort. The remaining 10 percent is used for a multiplicity of operations.

[3] Not applicable for offhand grinding but appears applicable for machine grinding.

Electroarcing, electrosparking, and electrolytic actions might occur simultaneously during a grinding or cutting operation. Machines predominantly operate on the basis of one of the processes but there may be other process mechanisms superimposed. The superimposition of more than one mechanism or process in a cutting or grinding operation could markedly alter the results obtained.

The ultrasonic technique might be used in combination with one of the electroprocesses such as the electrolytic one. However, this has not as yet been tested.

3. POTENTIAL APPLICATIONS OF NEW PROCESSES

To evaluate the applicability of new processes for machining and grinding, it is necessary to consider the pertinent or important job items or operations. The first consideration in the selection of job items is the current use of diamond bort for performing the operations in accordance with present day practices. These operations involve principally diamond-wheel grinding. In addition to those operations that currently use diamond bort, other finishing and forming operations of hard-to-machine materials, which are needed for our preparedness program, must be evaluated. Diamond-wheel grinding or some other form of diamond cutting might be suitable for some of these latter job items, but if they are to be produced in the large quantities anticipated for our preparedness pro-

gram, there aren't enough diamonds in the world to do the job because the diamond bort supply is hardly adequate to perform the operations currently underway.

On the following page are tabulated eight important machining and grinding type operations, which cover the important job items described above. They are listed in order of current diamond bort consumption and account for approximately 74 percent of the diamond bort consumed in the United States. This tabulation indicates the estimated applicability of the new machining and grinding methods, including diamond wheel grinding. These applicability ratings are based on current knowledge of methods as being developed in this country and they may change as new developments progress. The following describes in more detail the potential applications of the new machining and grinding processes as related to each of the eight operations or job items as listed in the table.

3.1. Sharpening of single-point tools [6]

Single-point tools considered in this report are made of cemented carbides mounted on a steel shank. Sharpening of these single-point tools is usually performed by flat offhand grinding operations using diamond grinding wheels. This operation accounts for approximately 30 percent of the diamond-bort consumption in this country, and as such is the largest single consumer of diamond bort. In addition to usually being a flat offhand grinding type of operation, the steel shank is usually ground separately from the cemented carbide with the use of an aluminum oxide grinding wheel. The effective area usually ground ranges from 0 to ½ square inch and small depths of metal are removed. The type of performances of resinoid bonded diamond wheels is shown in an appended report where the side of a cup wheel does the work.[7] Sharpening of single-point tools usually involves removal of stock from a flat surface although there may be occasional need for cutoff type of operations.

The specifications for as-sharpened single-point tools are not very exacting, but they usually require that no cracks be visible at 200 magnification and that the surface finish be better than 50 rms micro-inch.[8] Sharp edges are a prime requirement but there is no accepted specification on the sharpness of a tool, and the only way of judging the suitability is through performance.

If the operation of sharpening single-point tools is limited to flat offhand grinding, then only the electrolytic method or combinations of the electrolytic method with abrasive grinding appear promising with respect to applicability (see tabulation on p. 6). The process as currently known can be an offhand grinding operation by converting conventional metal-bonded diamond-wheel grinding machines through the addition of auxilliary equipment such as a rectifier and an electrolyte pump (appendix VI). Eight conventional types of grinding machines are now being converted to electrolytic grinding and these machines will operate to test the sharpening of single-point tools utilizing a combination of diamond-wheel scraping and electrolytic action. The electrolytic method produces no cracks and meets the finish specifications at all speeds of metal removal. Commercial performance and cost of the operation are indefinite and must yet be established.

If sharpening single-point tools is not limited to flat offhand grinding, then the electrosparking technique and the ultrasonic technique appear applicable as shown in the table on page 6. However, neither of these processes are, at the present time, adaptable to offhand grinding but they can be mechanized in machine grinding. Electrosparking methods have questionable cutting time for sharpening single-point tools. The equipment is somewhat more expensive than for the other methods and the operating cost is dependent on rate of cutting and finish desired. For finishes of 10–20 rms micro-inch the electrosparking techniques become more expensive. No machines are at present available for sharpening single-point tools by electrosparking methods and ordinarily about 1 year would be required for production of machines for this purpose. The ultrasonic technique produces no cracks or damage and meets the finish specifications required for single-point tools. However, the sharpness of the edges as produced by the ultrasonic method have yet to be tested. Sixteen ultrasonic machines are currently available for further test work on machine grinding of single-point tools (appendix VIII).

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[6] See appendix I, Grinding Requirements of Carbide Fabricators and Users.
[7] See appendix III, Performance of Diamond-Wheel Grinding.
[8] R.m.s.—root means square roughness micro-inches as measured by a profilometer.

The electroarcing process has been tested principally as a cutoff method but it produces rough finishes that do not meet specifications for single-point tools. However, experimental work is planned on machines designed to operate on a combination of electroarcing and electrolytic actions and this might prove promising for sharpening single-point tools.

3.2. Grinding single-point tool chip breakers

Some cemented carbide single-point tools require chip breaker grooves to be ground in them back of the cutting edge. Grinding these chip breakers accounts for approximately 20 percent of the currently consumed diamond bort. The conventional method for grinding chip breakers is by the use of diamond grinding wheels (appendix I).

The grinding of chip breakers is not a flat offhand grinding operation but requires machine grinding. The form is trough shaped and the grinding operation is for only small depths. Appreciably smaller effective grinding surface areas are present for forming chip breakers than for sharpening single-point tools, being in the order of from 0 to 0.2 square inch. The same type of specification on chip breakers hold as for single-point tools. There must be sharp edges, no cracks at 200 magnification, and better than a 50 r. m. s. microinch finish.

Of the new processes, the ultrasonic technique appears especially applicable for grinding single-point tool chip breakers (appendix VIII). This technique performs and produces a finished article in much the same manner as described for sharpening single-point tools, but the potential cost of grinding chip breakers appears better than for sharpening single-point tools by the ultrasonic process. In addition, a special shaped chip breaker groove might be inserted in a single inexpensive manner by the ultrasonic technique. However, the sharp edges have yet to be tested.

As shown in the tabulation on page 6, the electrolytic and electrosparking processes appear applicable to grinding single-point tool chip breakers. The electrolytic method meets the finish specifications, and as in the single-point tool sharpening, conventional grinding machines might be converted. But because grinding chip breakers is a machine grinding operation, the conversion will be more extensive. At the present time one machine is being converted to operate by a combination electrolytic and diamond wheel grinding. The rate of metal removal by the electrolytic process for forming chip breakers is not so favorable as for sharpening single-point tools because of smaller effective grinding areas involved. The electrosparking technique can be mechanized for forming chip breakers, but the cutting time is questionable, the cost of the operation is dependent on the rate of cutting, and the technique is more expensive for the better finishes in the range between 10 and 20 r. m. s. microinch. Although at least seven electrosparking type machines are now available, about 1 year will be required for construction of machines for adaptation to forming chip breakers.

The electroarcing process appears to be of questionable applicability for grinding chip breakers because the finish is rough and damage is possible. However, a combination of the electroarcing process with the electrolytic process in one machine may prove promising.

3.3. Sharpening milling cutters and broaches

Milling cutters or broaches are made with sintered carbide teeth and consist, in effect, of several single-point type tools mounted in a body. Each tooth of the milling cutter or broach is usually ground separately, using diamond grinding wheels in a special setup. The teeth are ground to a small depth and the effective area of grinding is between 0 and one-half square inch. Sharpening of milling cutters and broaches accounts for approximately 15 percent of the total diamond bort consumed in this country.

Specifications required on as-sharpened milling cutters and broaches are similar to those for as-sharpened single point tools. That is, no cracks must be visible at 200 magnification, sharp edges must be effected, and the finish must be better than 50 r. m. s. microinch.

Because the operation is machine grinding, diamond wheel grinding is somewhat more costly for sharpening single-point tools. A cup wheel is usually used for this operation.

The tabulation on page 6 shows that the electrolytic, the electrosparking, and the ultrasonic processes appear applicable for sharpening milling cutters and broaches, but there are no machines available for testing this operation since

it requires a special arrangement and setup. The electroarcing process is of questionable applicability for this operation. For each of the new methods, the conclusions derived on sharpening single-point tools are expected to hold for sharpening milling cutters and broaches.

3.4. Grinding projectile cores

Projectile cores are made of cemented carbides weighing from 4 to 12 pounds and the grinding operations are usually flat base or ogive type. Unlike the sharpening of tools, the effective area of grinding is large, namely, between 2 and 10 square inches. Grinding of projectile cores accounts for approximately 5 percent of the diamond bort consumption in this country.

All of the new methods (with the exception of the electroarcing process) appear applicable or promising for grinding projectile cores but very little, if any, experimental work has been done to be able to evaluate these new techniques as applied to the grinding of projectile cores. If cemented carbide projectile cores are to be produced in much larger quantities for our preparedness program, then these new processes should be tested for this application since there may not be sufficient diamond bort to do the job.

3.5. Shaping and finishing dies

Many dies of a variety of shapes are made of cemented carbides, and they include wire drawing dies, blanking dies, and punching dies. Approximately 4 percent of the total diamond bort consumption is used for shaping and finishing these dies (appendix I).

The table on page 6 shows that, in addition to diamond wheel grinding, the electrosparking process and the ultrasonic process are in commercial use. There are currently six mechanized electrosparking type machines in use for shaping and finishing dies. The equipment is somewhat expensive and the cost is dependent on the rate of cutting and the finish desired. The ultrasonic technique has 16 machines in operation and incurs no cracks or damage to the finished dies. Both the ultrasonic and the electrosparking processes are used in operations for all but the final lapping, and they are more versatile than diamond wheel grinding. The economics on these processes appear satisfactory because they are in competition with diamond wheel grinding. For producing shaped holes, these techniques are more suitable than diamond wheel grinding.

The electrolytic method and the electroarcing method appear to be of limited applicability or are not applicable for shaping and finishing dies (see table on page 6).

3.6. Forming of turbine bucket attachments[9]

Turbine bucket attachments are usually made of nickel-cobalt super alloys or cemented carbides of intricate shapes with up to 2 square inches of shaping area. Stock removal is from light to heavy, from 0.05 inch to one-half inch. The surface finish must be less than 25 r. m. s. microinch, tolerances are as close as 0.0003 inch and shaping must be very close. At the present time grinding of the alloy types is accomplished by such means as crush form grinding, using aluminum oxide wheels. For sintered carbides, such as cemented titanium carbide, no method for quantity production is, as yet, established. Diamond form grinding does not appear promising because it is too slow and too expensive. If the number of turbine blades required is in the hundreds of thousands per month, forming time required per attachment must be only a few minutes.

The electrosparking, ultrasonic, and electrolytic techniques appear promising for forming of turbine bucket attachments, at least for part of the operations. The electroarcing process appears of questionable applicability because it cannot meet finish and tolerance specifications.

3.7. Rifling of gun barrels

In the event of much increased production of machine guns for our preparedness program, faster and better methods for machining and grinding will be very helpful and the new processes may find their applications in the field of rifling hard-to-machine materials used in gun barrels or gun barrel liners.

As shown in the table on page 6, the electrosparking and ultrasonic techniques appear applicable for rifling of gun barrels. The electrolytic and electroarcing processes are questionable applicability.

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[9] See appendix IV, The Forming of Gas Turbine Engine Blade Fastenings.

3.8. Machine and grinding of compressor disks

There is considerable research and development work under way to utilize high strength titanium alloys (more than 125,000 psi) in jet engine components, particularly for compressor disks. However, there has been considerable difficulty experienced in machining and grinding these titanium alloys by conventional methods. Lathe tools, for example, seize and wear rapidly, and aluminum oxide grinding wheels are consumed very fast. Therefore, conventional machining and grinding operations on these titanium alloys are slowed down considerably.

Diamond wheel grinding is applicable for this purpose, but it may be too expensive and slow. The new processes, with the possible exception of the electroarcing process, appear applicable and promising. The electrolytic process in particular appears especially applicable for machining and grinding titanium alloy compressor disks.

4. CONCLUSIONS

Most of the new processes and the combinations thereof appear promising as methods for conserving diamond bort for shaping and finishing sintered carbides and for performing operations on other hard-to-machine materials for important military end use items. Performance and costs for these new processes are not as yet well established.

The electrolytic process appears very promising as a means for flat offhand grinding as applied to sharpening of single point tools. Since this application is the largest single consumer of diamond bort, the rapid development of this process for sharpening of single point tools offers possibilities for substantial relief of diamond bort. However, there are tens of thousands of diamond wheel grinders used for sharpening single point tools, and it would be necessary to bring in or convert at least thousands of machines to show any appreciable effect. Additional experimental work must be completed before these machines are ready for mass production.

The second most prolific consumer of diamond bort is the grinding of single-point tool chip breakers. The ultrasonic technique appears to be adaptable for this purpose. Additional experimental work is necessary to properly appraise the method.

The sharpening of milling cutters and broaches and the grinding of projectile cores account for a substantial consumption of diamond bort. The electrolytic, electrosparking, ultrasonic processes, and combinations of them, look like possibilities for these applications; but experimental programs in these fields have yet to be started.

On the forming of cemented carbide turbine bucket attachments and machining and grinding of titanium compressor disks, no commercial methods have been established and it may be necessary to develop some of the new processes at a very rapid rate to meet the demands of possible increased production for the military. The electrosparking and ultrasonic processes appear applicable for forming turbine bucket attachments and rifling of gun barrels, the electrolytic process appears promising for machining and grinding of compressor disks.

None of the new processes are in actual commercial use except for shaping and finishing dies. However, a limited number of machines, based on these new processes, are becoming available for practical test work. For producing tools such as single-point tools, chip breakers, milling cutters and broaches, it will be necessary to carry the development work on these new processes through fairly extensive performance tests. These tests should not only be made on the machines but also on the tools themselves in order to adequately establish them as production units. At the same time research and development on machine improvements and on learning more fundamentals should proceed in a more intensified manner. The performance tests might best be done in production shops and eventually they must be done there. However, it may be worthwhile to design special programs for accelerated performance tests to exploit the methods as rapidly as possible. Performance tests and other research and development should be carried out mainly by industry who have the real need for these new processes.

5. RECOMMENDATIONS

Recognizing that several new processes for machining and grinding appear to offer promise both for saving diamond bort and for shaping materials urgently needed for our preparedness program, and that the rate of development effort

should be accelerated to bring these methods into form suitable for large scale testing, it is recommended that:

5.1. The Army, Navy, and Air Force explore the application of these processes to relieve potential bottlenecks or shortages and allocate or seek funds in the furtherance of these objectives where Government incentive is required

In the event that the military services are satisfied that the development of a particular technique is essential in the production of military weapons and equipment, the Government will have a high incentive to participate in programs which will accelerate the development of these techniques. One of the fields which can be profitably and efficiently sponsored by Government agencies is in the area of fundamental and basic research. Fundamental and basic programs will provide essential background information to industry for their machine development work after industry outlines the type of information which would be most helpful.

5.2. Industry should be encouraged to accelerate its efforts in research, and in machine developments, and in performance tests toward bringing these processes into industrial use as soon as possible

Government can assist industry in a number of ways: (*a*) By making available needed equipment and supplies; (*b*) by calling attention to urgently needed military end items which might require new machining and grinding processes; and (*c*) by issuing contracts to industry for specific end item prototypes requiring the new processes.

5.3. An educational program should be undertaken

Tool users and others should be made aware of the critical diamond bort supply problem in relationship to their operations. The wasteful use of diamond bort should be discouraged. In addition, publicity should be given to the new promising processes which might in time relieve the diamond bort shortage. The educational program may take on a variety of forms and could be handled in part by a proper Government agency, such as NPA, which is primarily concerned with the diamond bort supply problem. Others, such as editors of trade journals, technical societies, and specific industrial organizations, should be asked to participate in any educational program.

5.4 A committee should be set up to disseminate present and future pertinent information dealing with machining and grinding processes for use of governmental agencies

It appears important that there be some centralization of liaison and coordination so that the different Government agencies can be properly informed and advised with a minimum of unnecessary duplication of effort. For example, the Office of Technical Information Service, Commerce Department, or the Armed Services Technical Information Agency, Department of Defense, are in a position to undertake this assignment.

6. APPENDIXES

At the panel meeting, held on December 12 and 13, 1951, several reports, bearing on the evaluation of new processes for machining and grinding, were presented by individuals at the request of the Minerals and Metals Advisory Board of the National Research Council. These reports are appended as follows:

Appendix I. Grinding Requirements of Carbide Fabricators and Users by John C. Redmond, Kennametal, Inc., Latrobe, Pa., and Ford C. Ritner, Carboloy Department, General Electric Co., Detroit, Mich.

Appendix II. The Diamond Bort Supply Problem by Max N. Felker, NPA, Washington, D. C.

Appendix III. Performance of Diamond Wheel Grinding by H. W. Wagner, Norton Co., Worcester, Mass.

Appendix IV. The Forming of Gas Turbine Engine Blade Fastenings by John C. Redmond, Kennametal, Inc., Latrobe, Pa.

Appendix V. European Activities on Electro-Processes for Machining and Grinding by L. H. Metzger, Super-Cut, Inc., Chicago, Ill.

Appendix VI. The Electrolytic Process for Shaping Metals and Metal Carbides by George Keeleric, United Drill & Tool Corp., Chicago, Ill.; Howard T. Francis, Armour Research Foundation, Chicago, Ill.; and Charles L. Faust, Battelle Memorial Institute, Columbus, Ohio.

Appendix VII. Electro-Sparking Process for Shaping Carbides by Ian McKechnie,

Chrysler Central Engineering, Detroit, Mich., and D. F. Dickey, Firth Sterling Steel & Carbide Corp., Pittsburgh, Pa.

Appendix VIII. Ultrasonic Grinding and Machining of Both Metals and Nonmetals by Arthur Kuris, Cavitron Equipment Co., New York, N. Y.

Appendix IX. Electro-Erosive Machining of Hard Metals and Carbides by I. Weber and G. F. Nordblom, Frankford Arsenal, Philadelphia, Pa.

APPENDIX I

GRINDING REQUIREMENTS OF CARBIDE FABRICATORS AND USERS

(By John C. Redmond, Kennametal, Inc., and Ford C. Ritner, Carboloy Department, General Electric Co.)

I. INTRODUCTION

Cemented carbide compositions have come to be widely recognized and accepted as excellent for a wide range of industrial cutting and wear applications. However, it is doubtful if American industry's absolute reliance on carbide tools is always recognized. Most machining operations which are now done with carbide would require several times the machine tools and manpower to produce equivalent volume. In these days of the shortage of certain elements, it is of interest that a pound of tungsten will do 70 to 100 times as much work in the form of tungsten carbide as in high-speed steel. There are many important machining operations which cannot be done by any other means.

Commercial cemented carbides are products of powder metallurgy, made of very finely divided carbide particles of the refractory metals, cemented together by a metal or alloy of the iron group, forming a body of great hardness and high compressive strength.

Cemented carbides were first used for wire-drawing dies, from which the application expanded to include all types of drawing dies for round and irregular shapes, and cutting tools for machining all kinds of materials. In addition, cemented carbides have been used for machine and instrument parts and for a wide variety of products where high rigidity and resistance to wear are important.

In general, cemented carbides come under the two broad classifications that follow, depending on their uses.

1. The straight tungsten carbide with cobalt binder is used in tools for cutting cast iron, nonferrous metals, and nonmetallic materials; and in dies for drawing wire, bar, tube, and sheet metal, and for blanking; as well as for machine parts where resistance to wear is important.

Composition range:	*Percent*
Tungsten carbide	80–97
Cobalt	3–20

Hardness range: 84–93 Rockwell "A."
Density range: 13.40–15.35 grams/cm.^{3}
Transverse rupture strength range: 125,000–425,000 psi.

The steel-cutting grades consist largely of tungsten carbide with additions of titanium carbide or tantalum carbide or both, or of columbium carbide. These added constituents produce a material that resists cratering better than the straight tungsten carbide grades. ("Cratering," caused by the hot steel chip, is the formation of a cavity in the top surface of the carbide blank, slightly behind the cutting edge.)

Composition range:	*Percent*
Tungsten carbide	61–93
Cobalt	3–25
Tantalum carbide	1–27
Titanium carbide	15–32

Hardness range: 84–93 Rockwell "A."
Density range: 8.80–15.20 grams/cm.^{3}
Transverse rupture strength range: 100,000–325,000 psi.

Basically, the process consists of preparing the powder carbides of tungsten, titanium, or tantalum; mixing one or more of these carbides with a binder, such as cobalt powder; pressing the blended powder into compacts of desired form; and sintering molded shapes to achieve consolidation.

Compacting and sintering

The prepared powders are formed into shape for commercial use by (1) cold pressing, followed by sintering; (2) by hot pressing, during which the pressing and sintering are done simultaneously; (3) by extrusion, in this process the prepared powders are mixed with a plasticizer. The plastic material is extruded through a die, baked at low temperature, presintered, and sintered.

Applications

Cutting tools.—Grades of commercial cemented carbides are available to meet almost any machining requirement.

Ordinarily, where cemented carbides are used in the construction of tools, a small piece of the carbide material is brazed or fastened mechanically to a steel shank that provides a rigid support under the cutting edge.

The grinding or sharpening of cemented carbide tools is not particularly difficult so long as certain precautions are observed. Silicon carbide and diamond-impregnated grinding wheels are used to grind the carbide, but the grinding of the steel shanks to which the carbide is attached, is done best with an aluminum oxide wheel. The customary procedure is to grind the portion of the steel shank that is not close to the carbide tip, with an aluminum oxide wheel, and then to grind the carbide with the silicon carbide or diamond wheel.

Cemented carbides may be used for cutting operations ranging from light finishing cuts at high speeds and light feeds, to heavy cuts with coarse feeds and slower speeds. Interrupted cuts on steel and other materials are common with tools designed for the purpose.

Cemented carbides are used in the following tools:

Single point lathe tools
Reamers
Counterbores
Spot facers
Counter sinks
Facing tools
Boring tools
Turning tools
Threading tools
Fly cutters
Form tools
Broaches
Core drills
Boring bars
Solid twist drills for nonferrous materials
Hi-Brinell drills
Small solid circular saws and large carbide-tipped circular saws
Milling cutters of all shapes, sizes, and kinds
Shear blades
Files, flat and rotary
Dental burrs
Planer tools
Bending tools
Gage contact points
Spinning tools
Hand scrapers
Brinell balls

Mining tools.—A rapidly developing and important recent use for carbides is in mining tools. As in the cutting tools, the carbide forms an insert in the cutting edge. Mining tools are universally of brazed construction so, as in the case of brazed cutting tools, the grinding of a composite structure is involved. While diamond wheels are frequently used to size the blanks in the fabrication of the tools, silicon carbide wheels serve for resharpening operations.

Types of mining tools are as follows: Coal-cutting machine bits, auger bits, rotary drill bits, percussion bits, core bits.

Dies.—The first commercial application of carbide dies was for the hot drawing of tungsten and molybdenum wire. The usage expanded rapidly, and within a few years carbide dies were generally employed for the cold drawing of wire made of steel, copper, aluminum, and other materials. Today a large percentage of wire, rod, and tubing smaller than 3½ inches in diameter is produced through these dies. In addition, considerable high-speed wire is drawn hot, using carbide dies.

Besides the application in wire, bar, and tubing field, cemented carbides are employed largely for the cold extrusion and heading of parts such as bolts and nails, and for the nosing of shell forgings.

Cemented carbides are used extensively in the blanking of steel, aluminum, and like metals and in the cupping, drawing, and redrawing of steel metal parts in sizes from small eyelets to cylinders 10 inches in diameter.

Carbide-tipped mandrels for sizing the inside diameter of all types of tubing, produce tubes with a fine finish inside and hold the wall thickness and dimensions of the hole within close tolerances.

Wear.—The practical application of cemented carbide for purposes of shaping materials both with and without cutting, is attributed to the properties of high hardness and great compressive strength required of a material to resist wear. During these operations for changing the form of materials, very high pressures are involved, and high temperatures are reached at the mating surfaces between work and tool. At elevated temperatures, cemented carbides retain their indentation hardness better than other metals and alloys. After final sintering, the cemented carbides are so hard that they can be shaped only by such operations as grinding, lapping and polishing with the hardest of abrasives, and boring, turning, and facing with a diamond tool. Cemented carbides are being used where wear occurs from the loss of dimensions by rubbing, fretting of assembled parts under high stresses without visible motion, and scoring from foreign abrasive particles between mating surfaces. Cemented carbides are used also as material for pads inserted in metal forming dies; seals or glands for sump pumps; guides used in the textile industry and in wire fabrications; guides, arbors, and the like in spring-forming machines; and various gages for inspection.

The following are additional applications:

Centers for grinders and lathes
Steady rest pads and rollers
Centerless grinder rests
Gagematic gages
Sizematic machines
Swaging dies
Dies and pungers for molding powders
Collets
Ball mill slugs
Rolls
Knurling wheel shafts
Spring coilings arbors, pitch tools, guides, and the like
Ways and gibs for machine tools
Thread and wire guides
Balls for ball valves
Spinning and burnishing tools
Liners for brick molds
Chill plates for hardening thin steel
Valve seats

II. THE GRINDING OF CARBIDE TOOLS

A. It is of interest from the standpoint of the grinding problem to follow carbide blanks from the producer through the final use. The blanks are produced by a relatively small number of companies who mold the powder to the shapes and sized desired and sinter them. The great majority of these blanks are shipped in this form by the carbide producers who themselves fabricate only a small percentage into tools. Most tools are fabricated either by numerous small shops who specialize in toolmaking or by the ultimate users themselves. Thus even in the tool fabrication, by far the largest amount of grinding is done not by the carbide produced but by the tool fabricator.

However, by far the largest amount of grinding, conservatively more than three-quarters, must be done by the ultimate user of the tool in the resharpening which is required. It is estimated that the resharpenings are between 5 and 10 per tool depending on the type and use. The amount of stock removal in each resharpening is generally considerably more than that in the original fabrication.

Thus, over 90 percent of carbide tool grinding problems is in the hands of others than the producers of carbide blanks.[1]

While silicon carbide grinding wheels may be used for some of the rough grinding, diamond grinding wheels have been found to be required for the majority of these grinding operations.

B. In the production of carbide blanks or nibs, the final sintering operation involves a shrinkage of approximately 50 percent by volume (0.2 inch per inch dimensionally). Particularly when complex shapes are being produced, the shrinkage of a given dimension cannot be predetermined with exactness because of the interrelation of shrinkages in other sections of the part and variables inherent in the preceding pressing and presintering operations.

One of the larger carbide producers uses the following stock allowances on unground carbide blanks:

Dimension:	*Tolerance (inches)*
Up to ⅜ inch	+0.015—0.000
⅜ through 1 inch	+0.020—0.000
1 inch through 2 inches	+0.040—0.000

[1] Experience of Norton Co. indicates that 24 percent of diamond grinding wheels used for carbide grinding go to manufacturers of tools.

The carbide industry has given and is continuing to give, much attention to processes and techniques for the production of blanks and nibs with minimum practicable stock allowances, and important advances have been made in this respect.

C. Finished tools vary as to the dimensional requirements of the carbide blank, in brazed-on type single point tools, such as are used for turning, boring, etc., where the carbide dimensions are not of particular importance and the fabrication is largely a matter of establishing the required cutting shape, in form tools, lamination dies, etc., the dimensional requirements are exacting. Insofar as possible the fabricator selects blanks from industry standard sizes such as those shown on the attached list for single point tools.

In the manufacture of the finished carbide article, the fabricator is mainly concerned with the removal of the oversize stock allowance of the sintered blank and the provision of chip breakers and special forms to produce the tool or part to the user's requirements. The provision of chip breakers is particularly noteworthy in that it requires a large consumption of diamond grinding wheels. The application of electromachining methods to this operation should be as readily adapted to this tool grinding operation as any.

D. The following types of standard grinding machines are used in the manufacture and regrinding of carbide tools:

Pedestal	Internal
Bench	Centerless
Surface	Profile
Tool and cutter	Cylindrical
Chip breaker	

Of these the most important are the pedestal, bench, surface, and chip breaker grinders.

Special grinding machines, frequently semiautomatic or automatic in operation have been developed for production grinding of certain types of carbide blanks and tools.

E. General requirements for process to replace diamond wheel grinding:

(*a*) Low-cost equipment or attachments.
(*b*) Comparable stock removal or one operator run several machines.
(*c*) Reproducibility of results (size and finish).
(*d*) Availability of required equipment and materials.
(*e*) Minimum risk of injury to carbide.
(*f*) Safety and health considerations.

F. In order to give some idea of the magnitude of the grinding requirements for tungsten carbide compositions for tool and general requirements, the following very rough estimations have been prepared:

The number of blanks to be produced for 1951 is estimated at 50 million or 100 percent more than 1950. It is estimated that 25 million of these blanks will be used in single point tools or twice as many as 1950.

The following is a breakdown of one major producer and is probably representative of the industry as a whole:

	Percent
Single point tools (¾ inch square shank and under)	32
Single point tools (over ¾ inch square shank)	8
Special tools	15
Mining and percussion	15
Wear parts	10
Standard dies	8
Special dies	12

It is estimated that 60 percent or 30 million blanks of the carbide used in the United States of America are in the form of standard blanks from lists such as the one referred to earlier.

Modified standard blanks and simple blanks made to user's specifications account for approximately 25 percent or 12,500,000 blanks of total usage.

Only approximately 15 percent of carbide applications require carbide blanks of complex shape such as are frequently used for form cutting tools, lamination dies, etc.

There is no basis for estimating with any degree of accuracy the quantity of carbide in cubic inches or other units which must be removed by grinding. The overall of the blanks will be about 3 million cubic inches.

III. CARBIDE CORE GRINDING

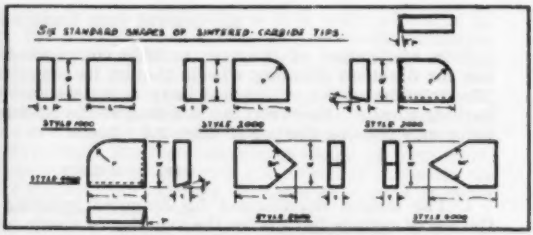
This application of tungsten carbide compositions constitutes an important use for diamond grinding wheels though its magnitude is somewhat indefinite. The grinding of the cylindrical body is satisfactorily accomplished with silicon carbide wheels. However, the grinding of the base requires, and grinding of the ogive may require, the use of diamond wheels.

IV. SUMMARY

1. The largest requirement for diamond grinding wheels in connection with the use of carbide tools is for the grinding of single point tools.
2. Something like 90 percent of the diamond grinding is done by the fabricators and ultimate users of the tools.
3. The grinding of chip breakers is an important single use of diamond wheels and any development of a substitute method would have marked influence on diamond consumption.

STANDARD SHAPES AND SIZES OF SINTERED-CARBIDE TIPS FOR SINGLE-POINT TOOLS

(These styles and shapes of sintered tips and the commercial catalog numbers have been adopted by the carbide manufacturing industries.)



Sizes and Commercial Catalog Numbers of Sintered-Carbide Tips for Single-Point Tools

Thickness t	Width w	Length l	Tip Style Numbers Stocked				Thickness t	Width w	Length l	Tip Style Numbers Stocked			
1/16	1/8	5/8	1010	2010			3/16	3/8	5/8	1380	2380		
1/16	3/16	1/4	1020	2020			3/16	3/8	3/4	1390	2390		
1/16	1/4	5/16	1030*	2030	3030		3/16	7/16	5/8	1300	2300		
							3/16	7/16	13/16	1310	2310		
3/32	3/16	5/16	1040	2040			3/16	1/2	1/2	1320*	2320		
3/32	3/16	1/2	1050*	2050			3/16	1/2	3/4	1330†	2330		
3/32	1/4	3/8	1060	2060			3/16	3/4	3/4	1340*	2340	5340	6340
3/32	1/4	1/2	1070*	2070									
							1/4	3/8	9/16	1350	3350	4350	
3/32	5/16	3/8	1080*	2080	3080	6080	1/4	3/8	3/4	1360	3360	4360	
3/32	3/8	3/8	1090*	2090			1/4	7/16	5/8	1370	3370	4370	
3/32	3/8	1/2	1100	2100	5100	6100	1/4	1/2	3/4	1380*	3380	4380	
3/32	7/16	1/2	1105*	2105	5105								
							1/4	9/16	1	1390	3390	4390	
1/8	3/16	3/4	1110*	2110			1/4	5/8	5/8	1400*	3400	4400	
1/8	1/4	1/2	1120*	2120			1/4	3/4	3/4	1405*	3405	4405	
1/8	1/4	5/8	1130	2130			1/4	3/4	1	1410†	3410	4410	5410
1/8	1/4	3/4	1140*	2140									
1/8	5/16	7/16	1150	2150			5/16	7/16	5/8	1420	3420	4420	
1/8	5/16	1/2	1160*	2160			5/16	7/16	15/16	1430	3430	4430	
							5/16	1/2	3/4	1440*	3440	4440	
1/8	5/16	5/8	1170*	2170			5/16	1/2	1	1450	3450	4450	
1/8	3/8	1/2	1180*	2180									
1/8	3/8	3/4	1190	2190			5/16	5/8	1	1460*	3460	4460	
1/8	1/2	1/2	1200*	2200	5200	6200	5/16	3/4	3/4	1470*	3470	4470	
1/8	1/2	3/4	1210†	2210			5/16	3/4	1	1475†	3475	4475	
1/8	3/4	3/4	1215	2215			5/16	3/4	1 1/4	1480†	3480	4480	
5/32	3/8	9/16	1220	2220			3/8	1/2	1	1500	3500	4500	
5/32	3/8	3/4	1230	2230			3/8	5/8	1	1510†	3510	4510	
5/32	5/8	5/8	1240*	2240	5240	6240	3/8	3/4	1 1/4	1520†	3520	4520	
							3/8	3/4	1 1/2	1525	3525	4525	
3/16	5/16	7/16	1250	2250									
3/16	5/16	5/8	1260*	2260			1/2	3/4	1 1/4	1540†	3540	4540	
3/16	3/8	1/2	1270*	2270			1/2	3/4	1 1/2	1550	3550	4550	

Tolerances: +0 — 0.000 on all no dimension up to 3 8 in.
+0.020 — 0.000 on d dimensions over 3 8 in. through 1 in.
+0.04 — 0.000 on c dimensions over 1 in. through 2 in.
Values of r are for the radius (n rounk. This radius on Styles 2000, 3000 and 4000 should be 1/8 in. for widths of tip 1/8 in. through 1/4 in.; 3/16 in. for widths of tip 9/32 in. through 3 8 in., and 1 4 in. for widths of tip over 3/8 in.
* Signifies 1/32 oversize on w ith excluding tolerance.
† Signifies 1/32 oversize on length e g tolerance.
This excess stock is provided to facilitate grinding of two opposite tip surfaces to size when for example, the tip extends entirely across the shank width.

Note: Extracted from American Standard Single Point Tools and Tool Posts (ASA B5.22-1950) published by The American Society of Mechanical Engineers. These standards also include the Standard Sizes of Shanks for Single-Point Sintered-Carbide-Tipped Tools.

These data are helpful where users prefer to assemble their own tools by brazing, or otherwise attaching, the carbide blanks to shanks. While some users prefer to buy the blanks and shanks separately, manufacturers of carbide tools also supply completely assembled tools in many forms and for many purposes.

Appendix II

The Diamond Bort Supply Problem

(By Max N. Felker, NPA)

The United States is totally dependent on outside sources for its supply of diamond bort. An increase of supply of this material is hoped for but not certain and will not be considered in this report.

The results of the recent NPA survey (form NPAF–120), submitted to the diamond industry concerning diamond bort consumption, imports, inventories, and amounts presently reclaimed for reuse, indicate a critical situation is rapidly developing and it is apparent that measures must be taken immediately toward conservation by all possible means. It is likewise apparent that the present use of bort within the carbide industry at this time precludes much further expansion of the hard-metal program unless better or substitute grinding methods are developed. Since it is not the purpose of this report to do other than present the factual data known to date, of current conditions, no attempt will be made to include other factors having a general bearing on the situation.

The following conclusions were drawn from the NPA survey, which covered 1950 and the first 6 months of 1951. While all forms have not been completed, enough have come in to form a reasonably accurate estimate.

INVENTORIES

Based on actual consumption reported, inventories of diamond bort in the hands of both manufacturers and dealers declined 8 percent in 1950 and showed a further decline of 9 percent for the first 6 months of 1951. The rate of decline for 1951 is, therefore, 18 percent. Also, the total amount of diamond bort held in all inventories (not including United States stockpile) is less than a 6 months' supply as applied against current usage.

Under "depth of chipping," the 0.0005 inch represents a D320 grit wheel and the 0.002 inch, a D100 grit wheel. Chipping is the breaking out of tiny particles at the edge where two ground surfaces intersect at an included angle of a little less than 90 degrees. The mating surface is that as ground by a 320-grit diamond wheel.

Chipping is irregular and varies from slightly more than the values quoted to much less. The lower limit of sawtooth pattern (grain marks) can be estimated roughly from the Profilometer readings. Multiply the Profilometer reading (in microinches) by about 5×10^{-6} to get the distance in inches from the bottom of the valleys to the top of the ridges. A Profilometer reading of 2 would then correspond to 0.000010 inch and a reading of 10 to 0.000050 inch.

3. GRINDING COSTS

Table 2 presents ranges of costs of cutting off and removing stock. They include some of the lowest costs we have obtained from laboratory grinding with diamond wheels.

Time costs are calculated only for contact time. Handling and other time spent on the job, outside of grinding contact, raises the time cost per unit of work ground in actual practice.

The work ground in all cases was marboloy cemented carbide. It was 44A grade, except for items 13 and 14 when it was 55A grade.

The operations tabulated should be generally taken as of rough grinding.

One basic figure assumed as common for all items of table 2 is: Time cost per hour, $7.50.

Appendix III

Performance of Diamond Wheel Grinding

(By H. W. Wagner, Norton Co.)

1. INTRODUCTION

The treatment in this report will be to outline the performance of which diamond wheels are capable and will assume that they are available at certain prices, as at present. Also the data will be limited to machining operations

which can be and are readily performed by the use of diamond wheels. It is recognized that electroerosion machining can drill holes and otherwise effect operations in small spaces where a diamond wheel is not applicable.

In the author's opinion, the most significant basis of comparison of competing processes is by means of total cost, per unit of acceptable product. The major elements of total cost are tool cost and time costs. The cost of spoiled work should also be included in the total cost.

Specifications for quality of work fulfilled by diamond wheels and grinding costs resulting from the use of diamond wheels will be given, for machining cemented carbide.

2. QUALITIES OF SURFACES PRODUCED ON CEMENTED CARBIDES

Table I

Profilometer roughness	2 to 10 (rms.)
Flatness from surface grinding	0.0002 inch
Depth of chipping of cutting edges of tools	0.0005–0.002 inch
Cracking of the work surface	None
Burn color left on work surface	None
Pitting of work surface	None

The qualities specified can be reached in commercial grinding without recourse to special equipment or methods. The finest finish (profilometer 2) of course requires a finer grit than that used for rough grinding. The flatness of 0.0002 inch requires going over the work with decreasing feeds, after rough grinding.

Consumption

Actual reported usage for the first 6 months of 1951 show an increase over 1950 of approximately 1,500,000 carats, based on a projection covering the entire year, together with a reasonable assumed rate of climb for the last 6 months.

Imports

Total imports for 1950 was reported as 5,322,000 carats. Available 1951 figures show bort being imported at the rate of 6,220,000 carats.

Reclamation for reuse

The amount of diamond bort reclaimed for reuse in diamond grinding wheels and other purposes, together with imports, constitute the total available supply for United States industry. The amount of this material reclaimed during the first 6 months of 1951 shows a substantial increase over 1950. An expansion of this program is now underway, but in all probability the amount of bort reclaimed per year will not materially increase above the present figure.

Summarizing the data presented by the NPA survey, an alarming picture of dwindling supply is shown. The current usage, as reported, exceeds the present rate of import and reclamation by approximately 500,000 carats for 1951.

It has been thought until recently that added supplies would be forthcoming for 1951 from mine sources, but this has not materialized. It is hoped that an increase of supply will be available during 1952, but this will not be known until after the first of the coming year and in any event will not materially affect the present or future picture as any great increase from mine source cannot be counted on.

It is evident, therefore, that immediate measures must be taken to develop new methods, not utilizing diamond bort, in grinding and forming tungsten carbide and other hard metals.

TABLE 2.—*Grinding costs, cemented carbides*

Item No.	Operation	Work size	Production per hour	Costs per unit of work		
				Wheel	Time	Total
			Square inches			
1	Cutoff	0.325 by 0.511 inch section	15.8	$0.42	$0.47	$0.89
2	do	do	16.2	2.96	.46	3.42
3	do	do	34.2	1.33	.22	1.55
			Cubic inches			
4	Surface, periphery	9 square inch surface	1.225	2.20	6.10	8.30
5	do	do	4.37	7.87	1.70	9.57
6	do	do	1.20	2.18	6.25	8.43
7	do	do	4.30	8.03	1.71	9.74
8	do	do	4.62	13.65	1.62	15.27
9	Surface, side of cup wheel.	0.625 square inch surface	.148	10.98	50.60	61.58
10	do	do	.148	9.30	50.60	59.90
11	do	do	.1485	7.79	50.55	58.34
12	do	do	.291	25.70	25.80	51.50
13	Centerless	1½ to 2-inch diameter	29.4	4.71	.255	4.96
14	Cylindrical	do	50.9	26.70	.147	26.85

NOTES

In table 2, "periphery" means that grinding was done with the periphery of the wheel. The periphery was used in all cases, except for items 9 to 12.

"Production per hour" is a calculated value. Sometimes the runs were of shorter duration than 1 hour. For items 9–12, total grinding was for more than 1 hour each.

The costs are per square inch cut in items 1–3 and per cubic inch of material removed in the other items.

The working rim on the side of the cup wheels (items 9–12) was ⅛-inch wide.

Table 3 gives further information pertaining to the items of table 2.

TABLE 3.—*Wheels, etc.*

Item No.	Wheel dimensions	Wheel structure	Approximate calculated price per cubic inch of diamond portion	Total work area cut or volume removed
	Inches			
1	8 by 0.055X—	D60–L100M ⅛	$370	0.306 square inches.
2	8 by 0.055X—	D60–L50M ⅛	278	0.162 square inches.
3	8 by 0.055X—	D100–L100M ⅛	370	0.322 square inches.
4, 5	7 by ½ by 1¼	D100–N100B ⅛	197	0.52 to 0.55 cubic inch.
6–8	7 by ½ by 1¼	D100–L100V ⅛	230	0.52 to 0.54 cubic inch.
9	6 by 1½ by 1¼	D120–J100B 7/16	215	0.370 cubic inch.
10	6 by 1½ by 1¼	D120–N100B 7/16	215	0.3705 cubic inch.
11, 12	6 by 1½ by 1¼	D120–R100B 7/16	215	0.36 to 0.37 cubic inch.
13, 14	20 by 3 by 12	D100–N100B 1/16	197	3.6 to 4.0 cubic inches.

NOTES

Under "wheel dimensions", the first figure is outside diameter, the second is thickness, and the third is hole diameter.

Under "wheel structure", D means diamond and the next figure is grit size. After the hyphen, the first letter is the grade, the next figure is concentration of diamond, and the final letter designates kind of bond. M means metal bond; B means resinoid bond; V means vitrified bond.

A higher concentration number means a higher volume percent of diamond.

The fraction following the bond letter is the depth (in inches) of the diamond portion. A greater depth usually costs less per cubic inch.

The price per cubic inch is based on maximum discount and is the net price of wheel divided by the cubic inch of diamond portion on the wheel.

4. ACKNOWLEDGMENT

Those of our staff who have worked up results for this report are B. H. Anderson, C. E. Sweetser, and L. P. Tarasov.

5. DISCUSSION

The comparatively high wheel cost of item 2 is due to the relatively rapid wear on the "50" concentration wheel on this particular operation.

Item 13 in the centerless group shows the lowest total cost per cubic inch of Carboloy removed. This is due mainly to the wide width (3 inches) of wheel face at work. A fast rate of cut is permitted without a high ratio of wheel wear to material removed.

Item 14 represents a faster rate of feed which resulted in much more, and more costly, wheel wear than in item 13.

Costs for items 9–12 are high because of the slow rates of cut encountered in the operation, which made the time costs per cubic inch high.

Internal cylindrical grinding does not happen to be included in the tables. It and other operations done with ordinary grinding wheels can also be done with diamond wheels. In practice, diamond wheels are generally not made in such large sizes as are those of aluminum oxide and silicon carbide. Diamond wheels are employed mostly for grinding hard nonductile materials such as cemented carbides, natural stone, and glass and other ceramics.

Appendix IV

The Forming of Gas Turbine Engine Blade Fastenings

(By John C. Redmond, Kennametal, Inc.)

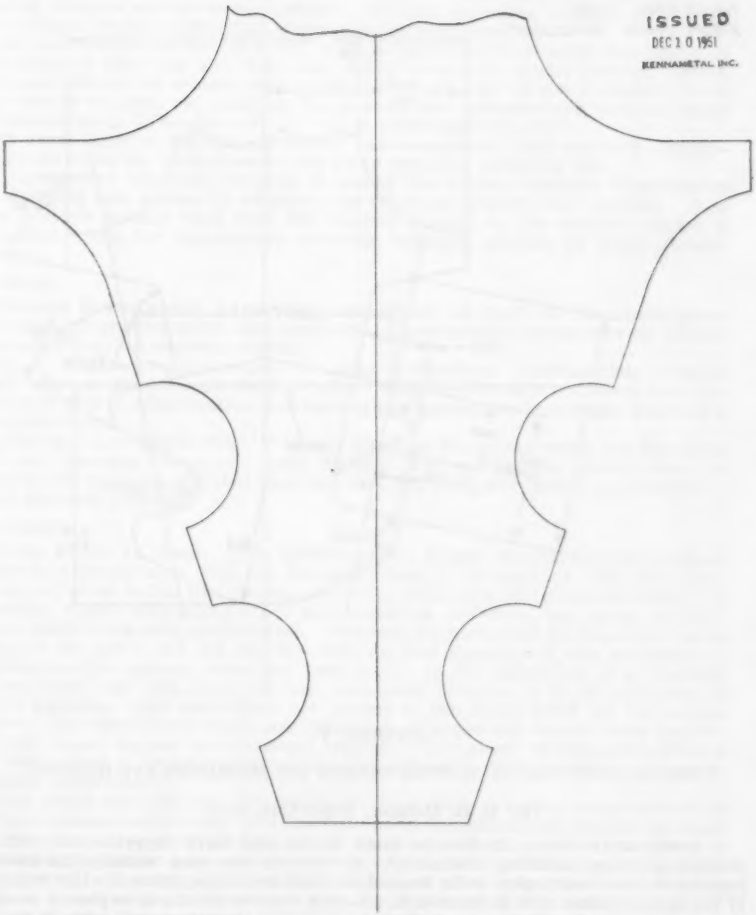
The rotating blades or buckets of gas turbine aircraft engines are now generally held in the turbine disc by a mechanical fastening. This fastening takes different forms such as the series of serrations referred to as the pine tree or a roll and many other forms. These must be made quite accurately both with regard to form and dimensional tolerances to fit the mating slots which are broached in the turbine disc.

The alloys of which such turbine blades are now generally made are sufficiently hard to machine that it is necessary to grind the fastening form by some such means as crush from grinding using aluminum oxide wheels. However, the quantities of blades which are required are mounting rapidly and in the event of a real emergency we have been told they would increase manifold. Hence, the new process methods may well have a place in the forming of roots on alloy blades.

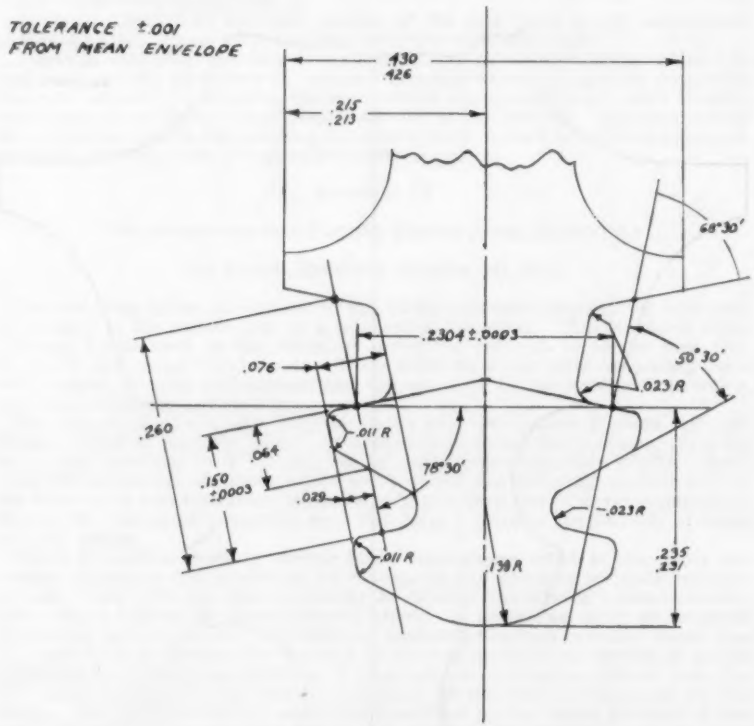
There is another phase of turbine blade development which is even more important as far as new processes for machining and grinding methods are concerned. This is in the work underway to develop less strategic metal ceramic materials to replace the presently used alloys. In particular, much work which is showing promise is now underway on cemented titanium carbide. Since this is a new field, no method for forming of roots in quantity production is as yet established. Crush form grinding, if applicable, will be more difficult than for the alloys because of the greater hardness of the carbide compared to the alloys. The problem will be somewhat simplified by the rough forming of the root. Diamond form grinding, which is being used for producing experimental root forms, is certainly not applicable because it is too slow and too expensive for such an application in production. The number of blades which will be required is in the hundreds of thousands per month. This will require a forming time per root of a very few minutes.

Two representative root forms are shown. It will be observed that dimensional tolerances are a few thousandths, overall tolerances ± 0.001 inch. Angular tolerances are a few minutes.

This problem should present a fertile field for new processes for machining and grinding.



5 X SIZE
REPRESENTATIVE MULTI PIN ROOT
FOR LARGE BLADE



APPENDIX V

EUROPEAN ACTIVITIES ON ELECTROPROCESSES FOR MACHINING AND GRINDING

(By L. H. Metzger, Super-Cut, Inc.)

A great many people in Europe know about and have experimented with carbide grinding, utilizing electricity. A visit to one spot usually discloses reports of other companies, some located in other countries, doing similar work. If the investigation is to be thorough, all such rumors should be explored, even though it may be found, upon arrival at the spot, that the report was false or that the experience was of little value.

PLANTS VISITED

England

In England, the plant of the Impregnated Diamond Products Co. at Gloucester was visited. Here it was found that the Russian literature was well known, and the articles had been read directly in the Russian. This concern had done quite a bit of work toward utilizing electroprocesses and recognized that the spacing of the work from the revolving disk was vital. They had worked on a machine utilizing a photoelectric cell to keep the tool properly spaced from the disk. This machine was not complete, but it is the writer's opinion that their experiments with it will continue. They had also worked on a setup whereby a

plain cast iron disk is used instead of a diamond wheel. With this would be used a variable-speed motor which would slowly move the tool toward the cast iron disc. The movement of the tool toward the cast-iron disc would be regulated by the amperage created during the process of stock removal from the tool. Thus, if the amperage went up, the tool would be stationary, or move very slowly until the amperage went down, at which time it would again be moved forward a very small distance. It was impossible to show this setup but further technical information regarding it was promised.

In connection with this, it would seem to the writer that while this might be practical if only one size tool were being ground, it would present certain problems where the contact area of the tool would vary in size constantly from one tool to another. In addition this concern had experimented with the ideas presented in: D. T. Vasil'ev (4), (6); B. R. Lazarenko (7), (8)[1]
The above articles describe electronic, electromagnetic, and solenoid arrangements to bring the work close to and away from the revolving disk.

Impregnated Diamond Products is one of the leading diamond wheelmakers in England and makes, in addition, the Wickman carbide tool grinder. It is the writer's opinion that they will shortly present to the English market a complete setup for successfully grinding tungsten carbide by some electro-process.

Holland

Hermes Metaalwaren Fabrieken, Amsterdam. A visit to the above plant revealed information given was incorrect. These people had never used electro-processes to grind tungsten carbide.

N. V. Wallramit Hardmetaal My. near Rotterdam. Investigation revealed that whereas these people were familiar with the Russian art, they had just begun to give it consideration and have not progressed sufficiently to warrant a detailed report.

Phillips Co. of Eindhoven. While in England, the writer met a top executive of this company who said that Phillips had progressed considerably in electrolytic grinding and that they had used diamond wheels and an electrolytic fluid for such grinding.

Germany

Vidia Krupp at Essen. This division of the Krupp Works, making tungsten carbide, experimented with the Russian ideas as far back as 1946 and 1947. Their activities fell in two groups. One with utilization of a diamond wheel and possibly wheels containing other nonconducting abrasives, the other utilizing plain metal disks with no abrasives. The only file that could be found gave data only on the latter and not the first activity, and therefore it was necessary to reconstruct by memory what had been done. In the utilization of a diamond wheel there was used direct current, employing between 15 to 20 volts and 30 to 40 amperes. The revolutions per minute of the wheel could not be remembered. The electrolytic fluid used consisted of 10-percent caustic soda and 90-percent water, as well as a standard type of "water glass" or high ratio silicate of soda solution (approximately 3.25 parts of silica dioxide (SiO_2) to 1 part sodium oxide (Na_2O).

The writer was told that the results obtained while grinding, using electricity with no pressure on the tool gave approximately the same speed of metal removal as when not using electricity in normal diamond grinding. When pressure was applied with electric current the speed of metal removal increased approximately 300 percent. However, this experiment stopped after they concluded that the edge or corner of the tool being ground seemed always to be rounded instead of a nice, sharp, square corner, which they prefer. Also they were not satisfied with the finish obtained.

Considerably more work was done in their second line of endeavor. This was done in conjunction with a Mr. Norbert Eberle, of St. Gallen, Switzerland, about whom more will be said later in this report. Here 2 types of experiments were conducted, 1 using direct current of from 15 to 20 volts, 30 to 40 amperes, and the other using alternating current up to 100 volts and permitting the amperage to develop volume according to the square-inch area of contact. In both experiments they again tried the same chemicals as mentioned above, namely, 10-percent caustic soda and 90-percent water, and a high ratio silicate of soda solution (approximately 3.25 parts of silica dioxide (SiO_2) to 1 part sodium oxide (Na_2O).

[1] See bibliography.

Experiments were conducted using first 1,750 revolutions per minute as well as 3,500 revolutions per minute. Some of their first tests involved using a brass disk 350 millimeters (13.8 inches diameter) and very thick. They then tried using a thin brass disk, 1½ millimeters (0.059 inch) as a cutoff disk. It was found that whenever such a brass disk was used the brass diffused into the contact surface of the tungsten carbide tool a distance of from 0.02 millimeters (0.00079 inch) to 0.06 millimeter (0.0024 inch). Subsequent tests proved this caused a softening of the cutting edges of the tools and shortening the life thereof. They also found microscopic cracks in the tools which had not been there before. Subsequent experiments were conducted using a chromium steel type of disk, but otherwise the same setups. These experiments produced no diffusion into the tungsten carbide, but they still produced microscopic cracks in the finish, both on the face as well as the edges of the tool, and this was not acceptable.

Accordingly Krupp had done nothing along these lines in several years, but advised that Mr. Eberle was continuing to experiment and was producing machines for this purpose.

Noxas Union Co. was visited at Frankfort, Germany. Here it was learned that the Eberle machine which the Krupp Works had mentioned was actually being made in conjunction with the efforts of Mr. Eberle. This machine was seen.

The method used by this machine employs no fluid at all. There is used alternating current up to 100 volts. The amperage developed is directly related to the square-inch area of contact of the tool against the wheel. The wheel is approximately 12-inch diameter with a thickness of 1¼. On each side outer face of the wheel, as well as across the periphery of the wheel, there have been machined multiple small grooves, about 1/32-inch wide, 1/16-inch deep, spaced about 3/32-inch apart, giving the effect of a corduroy surface. On the side faces these grooves run radially. On the periphery the grooves run parallel to the shaft rotating the wheel. It was explained that the purpose of the grooves was to cause just enough minute vibration to provide the spacing necessary or breaking of the current, and that this would happen even though the tool was held firmly in the fixture shown in the picture. Since no fluid of any kind is used, there is produuced when grinding what looks like a large arc extending down from the tool to about 1½ inches. This arc is sometimes blue and sometimes yellow. Because it was found that the metal of the disk or wheel diffuses into the metal of the tool being ground, it has been the practice of the maker to spray that portion of the disk or wheel that comes in contact with the tool, with a metal, composition of which is the same as the tool being ground. The exact technique of cold spraying the wheel was not given and was the only information withheld.

While this is much slower in grinding than electrolytic methods seen in the States, nevertheless it did seem to put a semipolish on the corner or edge of the tool being ground. After seeing this, the writer concluded that it was far too slow for usage in America, where grinding in production is much faster than this machine can provide, although it may have certain limited applications.

REPORTS OF OTHER ACTIVITIES

Questions were asked at all places visited regarding such grinding in Europe. The following is the information as summarized from the various reports given.

Germany

It was reported that Walter Tubingun, Baizy, were grinding tungsten carbide electrolytically as was the firm of Folkswagon, Braunchweig, Germany.

Belgium

No specific names of firms doing this in Belgium were given. On two occasions it was reported that in the last several years great progress has been made in Belgium in the grinding of tungsten carbide and that probably such developments would be found on investigation starting at Brussels. It is reported that the Syndicate in Belgium, owning diamond properties in the Congo, have started their own diamond wheel manufacture in Brussels and are interested in tungsten carbide plants in Belgium and the probability is that the latter will have done some work along the lines covered by this report.

France

While no definite company using electricity to grind carbide in France was reported, many reports indicated that the French likewise are on their toes as regards recent developments and a thorough investigation probably would reveal considerable activity.

Switzerland

Answers to queries generally point to more progress having been made in Switzerland, utilizing electricity for grinding carbide, than any other country in Europe and the following two names were given: Voegeli and Wirtz, Bien, Switzerland; Anthony Vogels & Son, Ltd., Pieterlen, Switzerland. In addition, Swiss Patent 257468 has been issued to Lazarenko, April 1949, which patent covers the grinding or machining of metals using electricity and a fluid (a translation has been made by the writer).

Obviously, there is considerable activity along these lines in Switzerland although no outstanding or startling results were reported.

England

Time prevented further investigation in England but it was reported that Wickman, who makes diamond wheels, is exhibiting in November 1951 a "Method X" machine and they will shortly be operating under a license from Firth Sterling for this machine in England. It was also reported that work had been done by the G. E. carbide plant in England, as well as the Murex Co., who make tungsten carbide. The type of work the latter two have done was not known definitely by the person reporting it but he felt that it was more or less along the lines of the process used by "Method X" and "Elox".

In England, British Patent 637872 covering electro-process was issued in May 1950 to Rudorff.

Italy

It was reported the Russian ideas had been experimented with in Italy but the person reporting it did not know the names of the firms who had so experimented.

CONCLUSIONS

It seems to the writer that certain definite conclusions can be reached, namely:

(1) That technicians in Europe know of the possibilities of grinding tungsten carbide, utilizing electricity as well as do the Russians and ourselves in America, and have read the literature.

(2) They have been, and will continue, to experiment towards perfecting better methods along these lines, regardless of their progress up to date.

(3) Generally speaking, they have not reached as satisfactory a degree of accomplishment to date as we have in America.

ACKNOWLEDGMENTS

In closing, the writer wishes to express sincere appreciation for the cooperation given by Dr. Amos Shaler, chief metallurgist engineer under Dr. Bell in the Division of Naval Research, United States Embassy, London, who so courteously and efficiently arranged for United States representatives as well as British representatives to give assistance at the various points visited. He would also like to express his thanks to Lt. Cdr. Fox in Naval Research in our Embassy at the Hague and Dr. R. M. Langer in Naval Research at our Embassy in Koblenz, as well as Dr. Frances of the British Embassy in Dusseldorf.

RECOMMENDATIONS

1. Review the industrial need for a new process for shaping carbides (or hard alloys).

2. If a need is found, the performance specifications that must be met by any new process should be cited.

3. If a need is found, the elestrolytic grinding prospects should be reviewed as to whether its potentialities are diminished because of the findings in 2, and if not, a research and development program should be considered for devising electrolytes and machines for electrolytic grinding, and the convertibility of presently used machinery to electrolytic grinding.

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Appendix VI

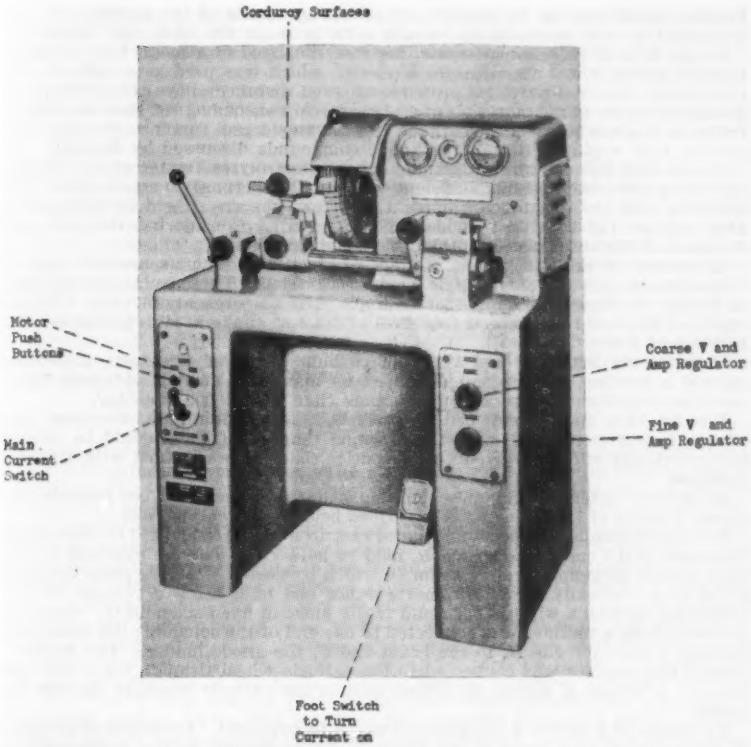
The Electrolytic Process for Shaping Metals and Metal Carriers

(By George Keeleric, United Drill & Tool Corp.; Howard T. Francis, Armour Research Foundation; and Charles L. Faust, Battelle Memorial Institute)

HISTORICAL BACKGROUND

The electrolytic process for shaping metals in its original form, proposed by Gusev (U. S. S. R.), concerns a method whereby metal is removed from a workpiece by what the Russians call electroerrosive action. In Gusev's method as described by Skornykov,[1] Popilov[2] and Noskov[3] (U. S. S. R.), a cathode consisting of a revolving metal disk slides against an anodic workpiece while an electrolyte is applied to the disk and workpiece in the same manner as a coolant is applied to a grinding wheel and work. The electrolyte, according to Popilov,

[1] Promyshlennaya Energetike 3, 1 (1946), 11.
[2] Zavodskaya Laboratoriya 14, 3 (1948), 358–361.
[3] Stanki I Instrument 19, 10 (1948), 20–22.


Corduroy Surfaces
Motor Push Buttons
Main Current Switch
Coarse V and Amp Regulator
Fine V and Amp Regulator
Foot Switch to Turn Current on

consists of technical water glass of suspensions of clays in 0.1 to 0.2 percent NaOH solutions.

The pressure applied to the workpiece against the revolving disk may, according to Noskov, vary from 0 to 1 kg/cm², with optimum stock removals obtained at 0.6 kg/cm². The speed of the disk is recommended by Noskov to be from 8 to 12 m/sec. The voltage applied between disk and work is from 8 to 30 volt, with cutting rate proportionate, and the quality of finish is inversely proportional to the voltage applied. Gusev has, according to Noskov, explained: "* * * that the removal of metal proceeds both by electrochemical and mechanical action on the anode. The passage of direct current through the special electrolyte causes the formation of a film of insoluble compounds on the anode, protecting it from further electrolytic action. Removal of this protective film from the surface of the anode by the rotating wheel forming the cathode exposes a fresh surface of metal to the action of the electrolyte and thus assures the continuous removal of metal from the anode. * * *"

All the Russian authors mentioned above refer to the presence of sparking and/or arcing between cathode and anode, but also emphasize the need for keeping sparks and arcs at a minimum in order to minimize wear of the cathode. Lazarenko [4] refers to suggestions for electrolytes by K. K. Khrenov, who recommends solutions of sodium salts of nitric, hydrochloric, boric, silicic, and phosphoric acids as having arc-extinguishing properties.

RECENT EXPERIMENTS

On the basis of experiments with the method described by Popilov carried out in the laboratory of United Drill & Tool Corp., it is reasonable to assume that

[4] Stanki I Instrument 17, 12 (1947), 8–11.

Popilov metal removal is mainly carried out by means of the sparks and arcs generated in the intermittent contact area between the disk and workpiece.

In the first of these experiments, the disk consisted of a metal bonded single layer diamond wheel according to Keeleric,[5] which was used as a cathode. In this wheel, diamond particles protrude an even distance above the metal bond. As diamonds are abrasion resistant and electrical nonconductors, they are ideally suited as spacers between the cathode and the anode, and furthermore, they will provide that wiping action of the anode compounds discussed by Noskov.

It was thus found that when employing the electrolytes (water glass) according to Popilov and providing sufficient spacing (25 microns) to avoid arcing and sparking, only the insignificant current of a few amperes passed between anode and cathode (15–25 volts; anode area 0.74 cm^2). Considering the low conductance of the water glass solution, this is not surprising.

A number of other solutions of high conductivity, such as neutral salts of hydrochloric, sulfuric, and nitric acid, were tried. These solutions resulted in highly increased currents—for example, 150 amperes at 16 volts with an anode of hardened high speed tool steel of 0.8 cm^2 anode area (current density 18,400 amp/dm^2).

Experiments with sintered tungsten carbide pieces of the same dimension showed somewhat less current densities, as maximum current obtained under the same conditions did not amount to more than 4,000–9,000 amp/dm^2.

Besides high speed steel, ordinary steels, copper, aluminum, titanium, and alloys thereof were tried, and it was found that all of these could be shaped electrolytically with higher current densities than those obtained with sintered carbides.

In order to determine the most suitable spacing distance between cathode and anode, a series of experiments, as described below, were carried out.

The cathode consisted of a cup-shaped cast iron disk *A* (see fig. 1). The anode consisted of 0.5 cm diameter rod *B*, held in holder *C*. The cathode and holder were rigidly suspended from a beam *D*, which by means of needle point bearings could turn vertically at *E*. From the other end of a beam a plunger *F* was suspended in such a way that it could freely move in fixed solenoid *G*. The positive lead from a rectifier was connected to one end of the solenoid; the other end, through a mercury cup *H*, to the beam and *C*, the anode holder. The negative pole of the rectifier was connected to the cathode wheel through the brush and ring *I*. A weight *K* moves the adjustment of the cathode pressure against the anode.

By means of a switch *L* the solenoid might be bypassed. By means of a nozzle *M*, reservoir *N*, and pump *O*, an electrolyte was carried to the anode-cathode space. Ammeter *P* measures the constant direct current in the circuit. Ammeter *Q*, consisting of an A. C.-meter with a torroidal current transformer, measures any pulsating current which might be generated by sparks or arcs.

The current passing through the solenoid exerts a pull on the plunger, thereby increasing the distance between anode and cathode. By adjusting the position of the weight *K*, it was possible to keep a constant space between the wheel and the workpiece, as the weight would automatically feed in the work until the current reached a certain value, at which point the pull of the plunger would balance the force of the weight. This simple arrangement, unfortunately, would only work automatically when the area of the tool facing the wheel was constant, or in other words, when the current through the solenoid was substantially constant. In practical grinding, the area of the workpiece contacting the wheel, except for cylindrical grinding, is, of course, seldom constant.

With this electromagnetic automatic feed arrangement, it was found that high speed steels, cobalt, copper, aluminum, and titanium and its alloys could be shaped at high current densities without scraping or wiping off the anode film as demanded by Gusev's theory. A brown film was formed on steels, especially when the electrolyte was neutral or slightly alkaline, but this film seems not in any way to interfere with the speed of stock removal.

However, electrolytic "grinding" of sintered tungsten carbides could not be carried out with any of the electrolytes tested, without providing the wiping action of Gusev, by means of a metal bonded abrasive wheel, the abrasive acting as wipers (and spacers).

The following experiment might throw some light on this problem. A piece of tungsten carbide was made an anode at the anode current density of 1 amp/dm^2

[5] United States patent No. 2,368,473.

in four solutions. (1) 10 percent HCl, (2) 10 percent H_2SO_4, (3) 10 percent HNO_3 and (4) 40 g/l $NaNo_3$–20 g/l $NaC_2H_3O_2$ (pH 5.6). In all cases a heavy, adherent coating of apparently WO_3 was formed on the specimen. The color of the electrolytes indicated that the cobalt binder of the tungsten carbide particles formed salts of the acids employed.

The specimen in the sodium nitrate-sodium acetate electrolyte lost 0.87 grams in weight after 1 amp/hr., i. e. after the oxide (s) was mechanically removed from the specimen.

The current space-distance relationship was determined as follows: A double slit formica tube (fig. 2) was pressed over the specimen, the slits providing passage for the electrolyte. Initially, the slitted part of the tube would protrude 2.5 mm. over the edge of the specimen. The switch *L* was closed so as to short-circuit the solenoid. As grinding proceeded the cast-iron disk would wear the formica and wear it faster than the specimen was ground, thereby decreasing the gap between the specimen and the disk. At intervals the current was noted and the protrusion of the formica above the ground surface of the specimen was measured on a shadowgraph. The test was continued until sparks or arcs were generated and registered on the ammeter *Q*. Graphs obtained by plotting current against gap distance at different voltages and surface speeds are attached as figs. 3 and 4.

PRESENT STATUS OF ELECTROLYTIC GRINDING

A tentative and qualitative description of the phenomena associated with electrolytic grinding is as follows: The approximate rate of metal removal which has been achieved with high-speed steel is about 4 mm/mm. The current density required for such a removal rate is about 18,400 amp/dm^2. The coulombic efficiency of the process is in the vicinity of 90 percent. The voltage required for the attainment of the above cutting rate is in the range of 25–35 volts. The electrode spacing corresponding to the conditions described is about 20 microns.

Judging by the conditions described above, it appears that the very thin film between the workpiece and the cathode wheel is swept past the mating surfaces at sufficiently high velocity to prevent severe polarization of the electrodes. Such sweeping action also prevents generation of excessive temperatures in the electrolyte, since it is continuously being replaced by fresh solution at the average temperature of the bath. Several bits of evidence, however, point to the fact that a very definite polarization film exists immediately adjacent to the anode surface. This film seems to be extremely thin, and uniformly distributed on the anode surface, since the quality of finish obtained in electrolytic grinding is exceptionally good as a general rule. One typical sample, checked on a brush analyzer, showed 5 micro-inch r. m. s. Still another fact points to the existence of a thin polarization film at the anode: iron and other metals can be satisfactorily "electromachined" even when a neutral or slightly alkaline solution is used. This points to the existence of an acidic film immediately adjacent to the anode, caused by the polarization resulting from the extremely high current density employed.

From the results thus far obtained, electrolytic grinding appears applicable to any metal or alloy, provided only that the metal can be anodically dissolved at high rate. In tests made heretofore, tungsten carbide dissolved slower than metals. The background data encourage further study with tungsten carbide and other carbides. Present knowledge shows the direction such a study should take: (1) discovery of an electrolytic solution in which tungsten carbide (or other selected carbide) is convertible to "dislodgeable" products at very high anodic current density; and (2) provision of anodic conditions that set up the minimum polarization.

For work under (1) development of solutions of anodically very active anions, which also form very soluble tungsten or metal salts, would be highly desirable. Solubility is preferred to insoluble salt or insoluble oxide formation and removal of such by mechanical means during anodic dissolution.

Electrical and mechanical assistance is an added necessity on (2) to speed up the metal dissolution rate. One or both types of assistance can reduce the anodic polarization even of the most active electrolyte. Alternating current could be superior to direct current, because of lowering polarization, providing attack of the disk can be prevented. This is evident in the high rate that high current density a-c causes iron to dissolve in sodium cyanide solution, whereas d-c causes complete passivity. A cathode surface, provided with nonconducting spacers, will provide a wiping action that reduces polarizing films and removes loosened car-

bide particles or oxides of metals. The diamond-impregnated wheel mentioned previously is an example of the latter situation. Rotation of the cathode wheel and solution flow are needed to supply rapid agitation for removal of anodic products and renewal of solution in the cutting zone.

General experience in anodic dissolution of metals gained in electropolishing, electrodeburring, and electromachining is quite extensive, and can supply the details needed in a study to devise a method or methods for electrolytic grinding of carbides.

CONCLUSIONS AND RECOMMENDATIONS

Electrolytic grinding is an electrochemically sound procedure having very promising characteristics. The fact that fairly rapid metal removal can be achieved without the use of hard cutting materials and, in fact, without any wear at all on the cathode wheel surface, makes the method particularly attractive. Contoured wheels, for example, could be used for refinishing machine tools with a very minimum of redressing of the grinding wheel.

Electrolytic grinding will always be limited to the electrolyte in which a selected metal or alloy is anodically active. Electrolytic grinding requires that the electrolyte maintain very high anode current densities, and that rapid agitation should be provided to minimize polarization.

Electrolytic grinding should not consume the properly designed cathode disk. Although current densities will be high, the actual amperage will be in the realm of practical transmission limits and voltages are likely to be low enough to be without hazard to operators.

Technically, a process for electrolytic grinding of carbides and hard alloys appears attainable by further research development. Achievements of ultimate efficiency will depend on discovering an electrolyte (or electrolytes) as discussed herein. This is a problem for which electrochemical background is excellent.

Practically, a successful process depends on developing suitable electrical or mechanical control devices for spacing the cathode disk and for solution flow in the zone of electrolytic cutting.

Commercially, electrolytic grinding is simply another method for tool or surface shaping. Its use must stand on relative economics, special applicability or results, or relief of materials in short supply.

RECOMMENDATIONS

(1) Review the industrial need for a new process for shaping carbides (or hard alloys).

(2) If a need is found, the performance specifications that must be met by any new process should be cited.

(3) If a need is found, the electrolytic grinding prospects should be reviewed as to whether its potentialities are diminished because of the findings in (2), and if not, a research and development program should be considered for devising electrolytes and machines for electrolytic grinding, and the convertibility of presently used machinery to electrolytic grinding.

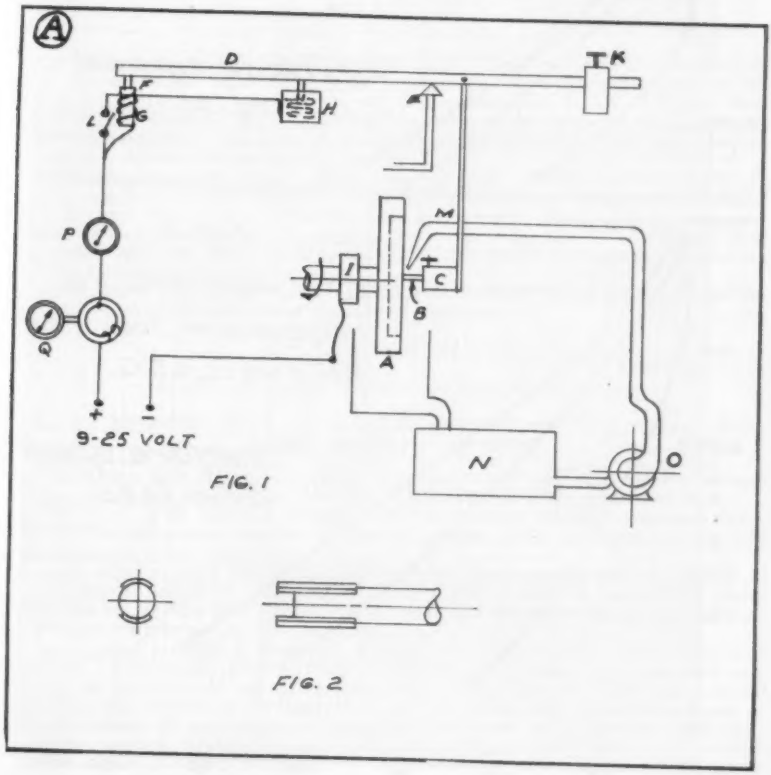
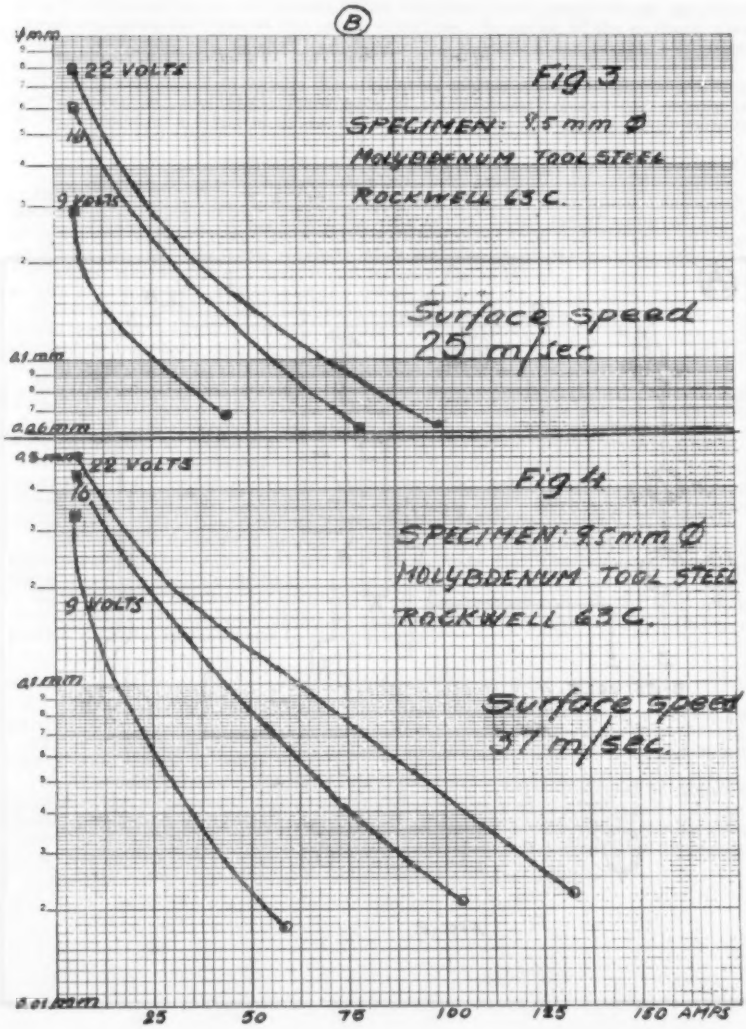


FIG. 1

FIG. 2



SUPPLEMENT TO THE REPORT ON THE ELECTROLYTIC PROCESS FOR SHAPING METALS AND METAL CARBIDES

Concerns rate of stock removal of tungsten carbide by means of electrolytic grinding.

Carboloy grade 999 and 883 respectively, in form of three-eighths-inch diameter cylindrical rods were fed perpendicular into a cup-shaped cathode wheel at different voltages and amperages. A spacing between the cathode wheel and the carboloy was obtained by 90–100 mesh diamond particles embedded in the cathode surface, the diamonds protruding less than one one-thousandth inch above the cathode surface. No more pressure than that necessary to keep the

work in contact with the diamond particles was employed. The following figures were obtained:

Specimen	Carboloy No.	Volts	Amperes	Grams per minute	Cubic inches per hour
A_2	999	0	0	0.04	0.00775
B_2	999	5	16	.3	.0725
B_3	999	10	24	.24	.058
A_1	999	15	36–38	.36	.0865
C_2	883	0	0	.02	.0049
C_1	883	5	16	.2	.049
D_1	883	10	24	.26	.036
D_2	883	15	36–38	.4	.098
G	883	15	36–38	.44	.108

The *p*H of the sodium nitrate solution varied from specimen A 1 to G from 7–8. Each sample was run at least 5 minutes. With the protrusion of the diamonds employed (spacing) during this experiment, higher voltages than 15 would result in sparks being generated between the cathode wheel and the carboloy specimens. The maximum current density obtained under these specific conditions was 345 ampere/square inches.

With smaller anode contact areas (of carboloy) a higher current density is obtainable (but a smaller absolute amperage) due to increased flow of the electrolytes. Conversely, at larger anode areas higher amperages are obtained but the current density will be slightly lower up to an area of one square inch at which point the efficiency falls off due to the faster dissipation of the electrolyte in the anode-cathode area.

The finishes obtained were below 15 microinches RMS for all the samples. The surface finish is independent of the rate of stock removal.

Appendix VII

Electric-Sparking Process for Shaping Carbides

(By Ian McKechnie, Chrysler Central Engineering, and D. F. Dickey, Firth Sterling Steel & Carbide Corp.)

We believe that the application of the electro-sparking machining technique to the shaping of tungsten carbide is a well-established and practical process.

The forming of internal shapes is currently being performed commercially, while external shapes, difficult to form by normal grinding techinques, are also being formed by this method.

Most effort to date has been directed to the formation of shapes difficult or impossible to attain by conventional processes and, for this reason, the direct substitution of this process for conventional machining methods is somewhat difficult to evaluate.

As in most machining processes, accuracy and cutting rates are interrelated factors. Accuracies of 0.0002 inch or less at low cutting rates are obtained, while the accuracy of repetitive operations is even greater. Material removal rates in the formation of internal apertures which leave a surface finish of approximately 50 microinch r. m. s. will currently run about 0.003 to 0.004 cubic inch per minute; however, removal rates do not necessarily reflect total volume removed, trepanning normally being used for large cuts. It should be emphasized that these cutting rates apply to machining tungsten carbides, since the composition of the materials being cut is a determining factor in the removal rate.

The use of present commercial equipment results in economies when applied to the removal of material from apertures which cannot be generated by rotation or in which appreciable thickness of cut is required.

To date very little effort has been directed toward the application of this process to the sharpening of tungsten carbide tools, but preliminary investigations and the Russian development reports indicate the practicability of the application. Even though cutting rates on external surfaces exceed the figures given above for internal apertures, the economic value of sharpening tungsten carbide tools by this method is unknown at this time.

While the sharpening of tungsten carbide tools by the diamond-grinding process tends to generate minute thermal cracking of the cutting edge, which

probably adversely affects tool life, it is believed that sharpening properly done by the electro-sparking method does not have this effect, although it is possible to produce cracks by improper operation.

There are at least two companies actively engaged in research and development programs directed toward the improvement and diversification of electro-sparking techniques. While it is expected that the projected rate of research will, within 1 year, result in machines which will cut many times faster, this program can be accelerated by supplying those presently engaged in research with effective directives for equipment, machine tools, and capital.

APPENDIX VIII

ULTRASONIC GRINDING AND MACHINING OF BOTH METALS AND NONMETALS

(By Arthur Kuris, Cavitron Equipment Co.)

This is a summary report on the ultrasonic process for grinding and machining both metals and nonmetals.

For over 6 years ultrasonic mechanical vibrations have been used to grind, machine, bore, and thread hard and brittle materials. This process is being applied on a rapidly increasing scale to commercial operations involving the cutting and machining of tungsten and titanium carbides, ferrites, sintered aluminum oxide, etc.

Ultrasonic processing is of particular importance in view of the diamond shortage because:

1. The process is best carried out with inexpensive boron carbide as an abrasive.
2. The process cuts all materials (both metals and nonmetals) which are ordinarily ground and machined with diamond and is the only process that will cut all hard materials that diamond will cut.
3. The process will cut an opening or recess of any shape or contour in carbides, ferrites, sintered aluminum oxide, etc., including the forming of internal threads and the making of complex extrusion dies, minting dies, stamping dies, embossing dies, etc.

THE PROCESS

In the ultrasonic process a tool is formed having an end of the shape of the desired hole, cavity, or contour which it is desired to cut. This tool is connected to a device which will cause the tool end to oscillate at very high frequency though low amplitude. The tool end is pressed against a workpiece and a mixture of finely divided abrasive (boron carbide) and water is flowed around and under the end of the tool on the face of the workpiece.

Ordinarily no movement of the tool is visible to the naked eye as the amplitude of movement of the tool at the high frequencies employed is very small.

Even though no movement of the tool end is visible, the tool, under light but continuous pressure, sinks into the workpiece (which may be a carbide or a ceramic body such as aluminum oxide or a ferrite) and a hole, aperture, or contour is formed in the shape or cross section corresponding directly to the shape of the tool end.

THE EQUIPMENT

The electronic oscillator and power supply are of standard design and are capable of delivering an alternating current to the transducer in the frequency range from 16,000 to 29,000 cycles per second. The power consumption of the machine is about 1 kilowatt.

The electromechanical transducer comprises a driving coil and water-cooled laminated magnetostrictive element. The linear dimensions of the element determine the frequency range of operation of the transducer which is operated near resonance for optimum efficiency. Commercial operations show that these transducers are continuously operable at high efficiency.

The toolholder is a conical element which is attached to the transducer assembly as easily as a drill is inserted in a drill press. The toolholder has a threaded extremity which is screwed into a female counterpart of the transducer whereupon it is tightened with a wrench. Setup and interchange of different types of tools is a simple and rapid process.

The working head of the toolholder carries an inexpensive steel tool in the shape of the hole, recess, or contour desired.

MATERIALS CUT, MACHINED, ETC.

The following materials can be cut, machined, bored, or threaded by ultrasonics:

Metals:
- Tungsten carbide
- Titanium carbide
- Zirconium boride
- Osium alloys
- Titanium alloys
- Hardened tool steel
- Tungsten
- Molybdenum
- Alnico
- Germanium

Nonmetals:
- Diamond
- Synthetic sapphire
- Quartz
- Ferrites
- Ferroelectric ceramics (such as barium titanate) and other ceramic materials
- Aluminum oxide
- Onyx
- Natural stone (such as flint, marble, granite, etc.)
- Glass
- Boron carbide

TOLERANCES, CUTTING RATES AND SURFACE FINISH

These are as follows:

(*a*) Roughing operations are normally carried out with accuracies of 0.002 inch.

(*b*) Greater accuracies are obtainable using finer grit sizes.

(*c*) Cutting rates vary with the material being worked and the amount and volume of material removed. Current work is being carried out at cutting rates which are sufficiently high to permit competitive operations.

(*d*) Finishes in roughing operations are in order of 25 microinches. Using finer abrasives, finer finishes are obtainable—up to and including a polished surface.

The process involves very low stress and no local heating. Accordingly, there is no thermal cracking, pitting, or burnt color left on the surface. The material being cut undergoes no chemical change, decomposition or alteration of physical properties.

The process has a 100 percent safety and health record for 6 years and the equipment can be operated by unskilled help.

SUMMARY

The most important fact about ultrasonic processing is that it can carry out all cutting, grinding, and machining operations currently requiring the use of diamond wheels, etc. Accordingly, the process naturally lends itself to replacing diamond in these operations.

Specifically, the ultrasonic process is immediately available for the grinding of chip breakers on a commercial scale. Existing equipment is set up to handle this operation on a competitive price basis with effective cutting rates and with low tool cost. Chip breakers are ground ultrasonically in from 30 seconds to 2 minutes with a tool cost under 5 cents and without complicated setups.

We suggest that steps be taken to utilize ultrasonic processing in grinding chip breakers.

We also suggest that steps be taken to evaluate other applications where ultrasonics can be used to cut down on the consumption of diamond bort. For example, in the grinding of single point carbide tools.

In conclusion, we should like to point out that ultrasonic machining is not limited to the treatment of carbides or sintered metals but is as readily applicable to machining nonconducting materials such as ferrites, titanates, quartz, synthetic sapphire and the like.

Appendix IX

Electro-Erosive Machining of Hard Metals and Carbides

(By I. Weber and G. F. Nordblom, Frankford Arsenal)

The introduction of cemented carbides in the machine tool industry, and their successful use in such tools as extrusion and swaging dies, form tools, single-point tools, and drills has resulted in a rapid increase in the rate of manufacture of parts for military and domestic use. Cemented carbides exhibit extreme hardness and wear-resistant properties and, therefore, carbide items are usually ground and polished to tolerance with diamond abrasive wheels and lapping dusts.

The machine tool industry of this country is largely dependent on the British diamond monopoly for a supply of industrial diamonds. During a time of war the demand for industrial diamonds would be greatly increased, and this country's present diamond stockpile would be of questionable duration. Any process which would obviate the need for industrial diamonds would, therefore, be of inestimable value.

Recent Russian reports[2,3,4,6,7,8] indicate that successful machining of cemented carbides and hard metals has been accomplished with various forms of electrical discharges. The Frankford Arsenal is investigating the principles involved in these methods, and is incorporating these principles in the development of a machine to enable the cutting and grinding of single-point and form cutting tools.

The method being investigated is a so-called contact method, and consists of the cemented carbide connected in a d-c circuit as the anode, and held in contact with a rotating mild steel disc, which acts as the cathode. The tool and rotating disc are immersed in an electrolyte, such as sodium silicate, and a capacitor bank connected in parallel with the electrodes may, if desired, be used. At this arsenal the capacitor bank is eliminated from the circuit. Both grinding and cutting may be achieved, depending on whether the carbide is held against the side or the edge of the rotating disc.

Cutting procedures have been thoroughly investigated and the following generalizations have been observed:

1. Pressure on the work has no effect on the cutting time over a practical range.
2. Minimum cutting time is obtained with sodium silicate as the electrolyte, and cutting time decreases with increasing sodium silicate concentration. Other electrolytes are inferior to sodium silicate in both respects.
3. Cutting time decreases with increasing current. However, little is gained by going beyond 100 amperes.
4. Cutting time decreases with increasing peripheral speed in the range, 10 to 40 feet per second, investigated. Beyond this range there is evidence that cutting time tends to increase with increasing peripheral speed.
5. Cutting time decreases with decreasing wheel thickness.
6. Cutting time is not affected by the hardness of the workpiece, but is affected by chemical composition.

In cutting procedures it has been concluded that the method is predominantly an arc-cutting process. If a gap is maintained between the rotating disc and the work, the only phenomenon occurring is electrochemical, and is represented by the formation of a silicate film on the anode. There is no possibility for a self-initiated sparkover, since the voltages seldom exceed 20 volts. In actual practice a gap between the electrodes is constantly being opened and closed as a result of natural vibration of the apparatus. At the moment the two electrodes separate, an arc is initiated and is maintained until quenched either by too large a gap distance or by the sodium silicate solution. The arc is of relatively long duration, and because the arc has a high integral temperature, erosion of the anode is predominantly a thermal effect.

During one cycle of natural vibration, the following phenomena occur consecutively: Arch erosion, electromchemical deposition of a silicate film on the anode, and direct short circuit. Deposition of a silicate film on the anode is

necessary for directing the forces of erosion toward the bottom of the cut, which is kept clean by the rotating disk.

The application of the method to a grinding procedure has not yet been thoroughly studied at the Frankford Arsenal. However, there is no reason to believe that the method, as used in grinding, is purely electroarcing. It is very likely that the principles of electrolytic, electrodeposition, electrosparking, and electroarcing phenomena may all play significant parts to a greater or lesser extent.

Preliminary investigations of grinding with the present apparatus have consistently resulted in surface finishes of about 5 microinch rms., and edges that are sharper and straighter than those produced through conventional diamond grinding. The technique involves the use of the side of a rotating disk, sodium silicate as the electrolyte, and current gradually decreasing from 20 amperes to 1 or 2 amperes over a 5-minute period.

The Cincinnati Milling Machine Co. is manufacturing for the Frankford Arsenal a machine which will incorporate the principles of the method being investigated, and will permit the following operations to be performed:

1. Straight cutoff and shaping.
2. Straight, radial and form grinding or polishing.
3. Boring.
4. Grinding of chip-breakers.

After investigations have been completed, it is probable that the machine will be redesigned and simplified for machine shop use. It is estimated that, using this machine, which will permit fine control of all the parameters involved in electroerosive machining, ground finishes better than 5 microinch rms. will result.

The method can be used successfully on the following operations, which presently require extensive use of diamond bort:

1. Sharpening of single-point tools;
2. Grinding single-point tool chip breakers;
3. Sharpening milling cutters and broaches (this operation requires a suitable indexing device);
4. Grinding propectile cores;
5. Forming of turbine bucket attachments;
6. Machining and grinding of compressor disks.

It is desired to emphasize at this point, that the method studied at the Frankford Arsenal will alone, except for techniques using abrasives, permit the following operations to be performed in sequence on one machine:

1. Cutoff of chipped or cracked portion of tool;
2. Regrind on 3 faces to a 5 microinch rms. finish or better;
3. Grind in a chip-breaker.

The use of the method for these operations will result in a saving of time as well as a major saving in diamond bort.

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Report No. MMAB–54–C
Copy No. 19

SECOND REPORT ON

NEW PROCESSES FOR MACHINING AND GRINDING

(Supplement to Report No. MAB–18–M Issued January 18, 1952)

By the Panel on New Processes for Machining and Grinding of the Minerals and Metals Advisory Board

This report prepared and submitted to the Administrator of GSA, Emergency Procurement Service (formerly the Defense Materials Procurement Agency), under contract DMP–23, between the Defense Materials Procurement Agency and the National Academy of Sciences.

Division of Engineering and Industrial Research, Division of Earth Sciences, National Academy of Sciences, National Research Council, Washington 25, D. C., July 1, 1953.

NATIONAL ACADEMY OF SCIENCES,
NATIONAL RESEARCH COUNCIL,
MINERALS AND METALS ADVISORY BOARD,
Washington 25, D. C., July 1, 1953.

DEAR SIR: I am forwarding herewith a second report on New Processes for Machining and Grinding which has been submitted through the National Academy of Sciences, National Research Council to the Administrator of the Emergency Procurement Service, GSA. This report has been reviewed and approved by a majority of the members of the panel on new processes for machining and grinding. It has also been reviewed by individual members of the Minerals and Metals Advisory Board who have competence in the field.

In accordance with an agreement with the GSA, Emergency Procurement Service, this report is being given the distribution indicated in the immediately following pages on the same date that it is being transmitted to the GSA. Therefore, as of this date, it has not been reviewed by the Emergency Procurement Service of General Service Administration.

Very truly yours,

FRANCIS C. FRARY, *Chairman.*

PREFACE

The Minerals and Metals Advisory Board, through the National Research Council, is distributing this report on new processes for machining and grinding to those agencies and individuals who have contributed to, or who will be concerned with the subject matter. This report is a report under contract DMP–23 between the GSA, Emergency Procurement Service (formerly the Defense Materials Procurement Agency), and the National Research Council, which was negotiated at the request of the DMPA.

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FOREWORD

On March 16, 1953, the Defense Materials Procurement Agency requested the Minerals and Metals Advisory Board to bring up to date Report No. MAB–18–M, issued January 18, 1952, on New Processes for Machining and Grinding.

The points to be covered in this report were specified as follows:

"1. The replacement of diamond bort and powder in industry by use of the substitute methods referred to in Report No. MAB–18–M, and any more recent methods.

"2. What research and other programs in Government and industry are presently being carried out to aid bort substitution?

"3. What further research and development is necessary to increase the possible substitution of diamond bort and powder?

"4. Any other comments or recommendations you may care to make."

In accordance with this request, this second report on New Processes for Machining and Grinding has been prepared by a panel of the Minerals and Metals Advisory Board of the National Research Council.

1. SUMMARY

Developments of new processes for machining and grinding, as possible alternates to the use of diamond bort, have made very rapid advances during the past 18 months (Jan. 1, 1952, to July 1, 1953). Research and development on new processes for machining and grinding has been sponsored principally by industry at a current rate of approximately $2 million a year. Research and development effort has been increasing rapidly each year during the past few years and the rate of increase is expected to continue. The emphasis of the research and development effort on various applications of the new processes is not entirely compatible with distribution of diamond bort consumption. To bring the development effort into closer balance with diamond bort usage, more emphasis should be placed on processes for sharpening milling cutters, broaches, and fluted tools, and surface, cylindrical, and internal grinding (cemented carbides).

Six classes of processes have been evaluated with respect to development status, economics, performance, availability, trade acceptance, and applicability (as of July 1, 1953). The classes of processes considered consist of electrodischarge processes, electrolytic processes, ultrasonic abrasive grinding, silicon carbide belt grinding, silicon carbide wheel grinding, and diamond wheel grinding. The new processes are still in their infancy with respect to production use; they are not yet ready to replace a substantial portion of the operations now requiring diamond bort. However, they are sufficiently developed so that progress in industrial use should be very rapid following the first year of an all-out emergency. In a peacetime economy, it is to be expected that each of the new processes will find its proper place in time.

Trade acceptance of new processes is a problem, and in some cases, more difficult to resolve than the technological problems. Adequate facilities for field test work in industry are lacking, and improvements in field test work should accelerate the bringing of new processes into production use.

Six new recommendations relative to new processes for machining and grinding are presented. These revise and supplement the four recommendations contained in Report MAB–18–M and point up the need for: (*a*) Industry's continued responsibility for research and development; (*b*) Government participation in research and development; (*c*) the desirability of continuing and extending industry's use of new machines; (*d*) a mechanism for periodic studying and reporting; (*e*) continued educational programs; and (*f*) consideration of collective action by industry to supplement and improve field test development work.

2. INTRODUCTION

On January 18, 1952, the Panel of the Minerals and Metals Advisory Board of the National Research Council issued report No. MAB–18–M entitled "New Processes for Machining and Grinding."[1] This report evaluated new processes for machining and grinding applications or operations where diamond bort[2] was being used, and several conclusions and recommendations relating to the development of these new processes were formulated and reported. During the past 18 months (January 1, 1952, to July 1, 1953), there has been such rapid advance in the development of these new processes for maching and grinding that a revision of report No. MAB–18–M was requested by the DMPA.

The primary objective of this report is to supplement report No. MAB–18–M by presenting factual information, made available during the past 18 months, and to bring forth new conclusions and recommendations based on these facts. The fact-gathering activities were undertaken by a small task group appointed by the chairman of the panel, and the conclusions and recommendations are based on contributions by panel members who are scientific and technical specialists in the pertinent fields relating to the subject matter.

3. THE DIAMOND BORT SITUATION

The only industrial diamonds considered in this report are crushing bort and diamond powder, herein referred to as diamond bort. The United States is still wholly dependent on outside sources for its supply of diamond bort; and,

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[1] Copies of this report (MAB–18–M) may be obtained from the Library Section, Office of Technical Services, U. S. Department of Commerce, Washington, D. C., at $2.25 per copy with checks made payable to "The Treasurer of the United States."

[2] For the purpose of this report, diamond bort refers only to crushing bort and diamond powder.

as predicted in report No. MAB–18–M,[3] a picture of supply in relation to possible industrial requirements, as developed between January 1, 1952, and July 1, 1953, has caused considerable concern.

3.1 General supply and demand

The rate of diamond bort consumption has been increasing sharply for the past few years, and this rate of increase is being maintained. Although imports have also increased, they have not kept pace with consumption. At the same time, cemented carbide production has been going up over the past 2 years at a much greater rate than either diamond bort consumption or imports. These data are illustrated in figure 1.

The curve of diamond bort consumption in figure 1 represents military and civilian use. Exports, which amount to less than 2 percent of consumption are not included. Consumption in 1953 will be controlled by available supply; it is understood that substantially larger amounts could be used.

The overall estimated supply of diamond bort will probably continue to increase moderately but it may not be at a rate sufficient to keep pace with requirements. The data in figure 1 on supply include imports and reclamation, but exclude stockpiling, inventory reduction, and the crushing of low grade industrial stones (resorting). The difference between consumption and supply (as shown in fig. 1) is accounted for by reduction in inventory and after resorting, but it is evident that as inventories are reduced consumption will be controlled by imports.

The expected much larger requirement for diamond bort to keep pace with the sharp increase in carbide production is shown clearly in figure 1. To account for the difference between diamond bort consumption and carbide production, silicon carbide wheels have been used more liberally, and improved techniques in the use of diamond wheels have relieved the situation. Furthermore, increase in carbide production did not require a proportional increase in diamond bort for shaping and finishing operations. NPA Order M–103, which encourages the use of silicon carbide wheels for rough grinding operations and restricts the use of resinoid bonded diamond wheels, has helped in reserving diamond bort for use in shaping and finishing increased quantities of cemented carbides.

3.2 Distribution of diamond bort consumption

Before new processes for machining and grinding can be evaluated, it is necessary to establish which machining and grinding types of operations are significant and their relative ranking. For this purpose, those applications or operations that are known to consume diamond bort were selected. To obtain the percent use of diamond bort for each of these selected applications, a special survey was conducted as described in appendix I. Figure 2 graphically illustrates the distribution of diamond bort consumption among seven selected applications. These applications account for essentially all the diamond bort consumed in this country and include bort used in grinding wheels, tools, and as loose powder. The miscellaneous classification constitutes, for example, diamond saws for concrete, stone, quartz, etc., drills, tools, gem stone cutting and polishing, polishing of jewel bearings, and use in compounds.

The data given in figure 2 are considered to be accurate within a few percent, and the ranking of applications with respect to order of consumption is clearly indicated. The percentages shown in figure 2 differ considerably from those reported in report No. MAB–18–M, and this difference should not be construed as entirely representing a shift in applications over the past 18 months. The data in report No. MAB–18–M were only an estimate, whereas those shown in Figure 2 are based on rather accurate surveys and represent a true picture of the diamond bort consumption.

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[3] See appendix II (MAB–18–M).

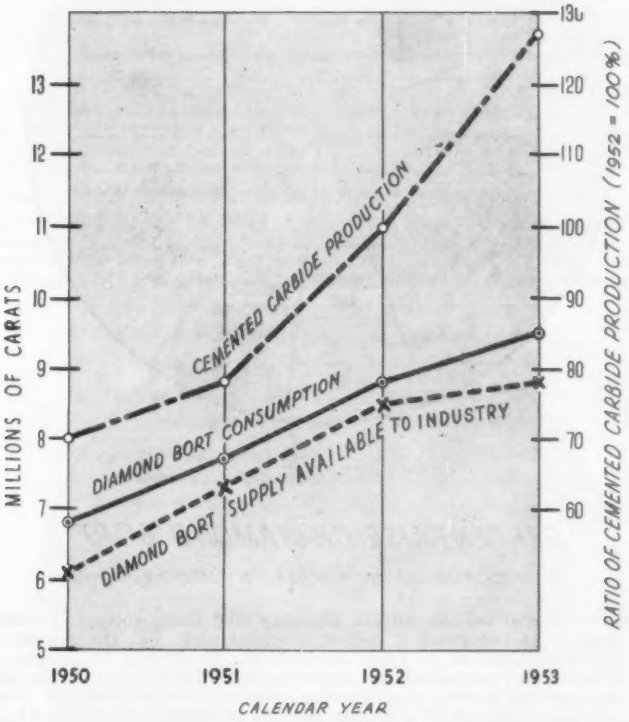

FIGURE 1

CONSUMPTION and SUPPLY of DIAMOND BORT and CEMENTED CARBIDE PRODUCTION

(YEAR 1953 ESTIMATED)

DATA ON BORT SUPPLIED BY N.P.A.
DATA ON CARBIDE SUBMITTED BY KENNAMETAL, Inc. and CARBOLOY DEPT. of GENERAL ELECTRIC CO.
4/23/53

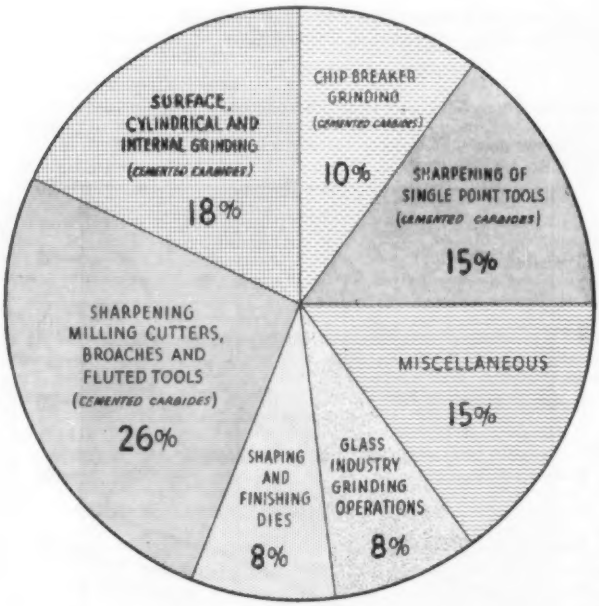

FIGURE 2

PERCENT USE OF DIAMOND BORT

(APPROXIMATE DISTRIBUTION IN U.S.A. – SEE APPENDIX I) 6/23/53

The sharpening of milling cutters, broaches, and fluted tools (cemented carbides) appears as the greatest use of diamond bort; but the sharpening of cemented carbide tools of all types accounts for more than 50 percent of the overall diamond bort consumption. Approximately 73 percent of all the diamond bort is consumed for shaping and finishing cemented carbide products. Grinding wheels and saws, used for all purposes, account for about 85 percent of the total diamond bort consumption.

Over the past few years, there has been a definite shift to machining and grinding of nonmetallic materials. The magnitude of this shift is about 5 percent of the total, but the trend is currently continuing and it is expected that even larger percentage use of diamond bort will find its place in machining and grinding nonmetallics in the future. In fact, it is probable that the current supply of diamond bort could eventually be used entirely in the nonmetallic field if the need were not urgent for machining and grinding cemented carbides.

3.3 New potential uses of diamond bort

In the preceding section, only those applications or operations where diamond bort is currently being used were considered. There are potentially new uses for diamond bort for shaping and finishing essential military items; but because of the limited supply, the Government and industry are rightly developing new processes that do not require diamond bort.

Silicon carbide belt grinding
Silicon carbide wheel grinding
Diamond wheel grinding

4.2 Distribution of research and development efforts for applications

The current research and development effort on all new processes as applied to selected machining and grinding operations is summarized in figure 3. It is evident by comparisons of figures 2 and 3 that the overall distribution of research and development is not entirely compatible with distribution of diamond-bort consumption. It appears that too much emphasis is being placed in some categories of applications and not enough in others, with the conservation of diamond bort being the principal objective. However, it is recognized that development work for a specific application may be helpful in other applications. For example, research and development results as applied to sharpening single-point tools should also be useful to the sharpening of milling cutters. This is particularly true for electrolytic processes, where a great deal of emphasis has been placed on the sharpening of single-point tools.

Figure 4 represents a breakdown of figure 3, wherein the distribution of research and development efforts for the selected applications are shown for each of the six processes. These data present a picture of the most natural, initial applications for each new process. That is to say, the research and development efforts are probably directed toward early production use.

4.3 Research and development volume

Figures 5 and 6 show the order of magnitude of money spent in research and development for each of 3 years, 1951, 1952, 1953, on the 6 processes. Annual volume is broken down into three areas of research and development, namely (*a*) basic research; (*b*) machine and process development; and (*c*) field tests.

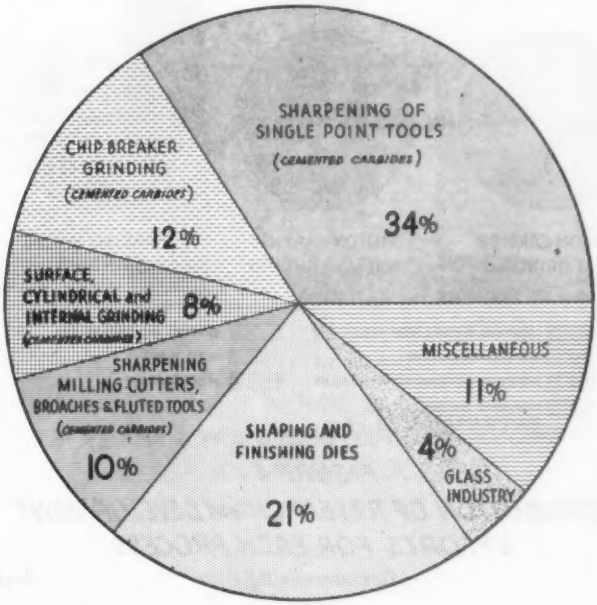

FIGURE 3

PERCENT DISTRIBUTION OF RESEARCH and DEVELOPMENT EFFORTS for SELECTED APPLICATIONS (ALL NEW PROCESSES CONSIDERED COLLECTIVELY SEE APPENDIX II)

6/23/53

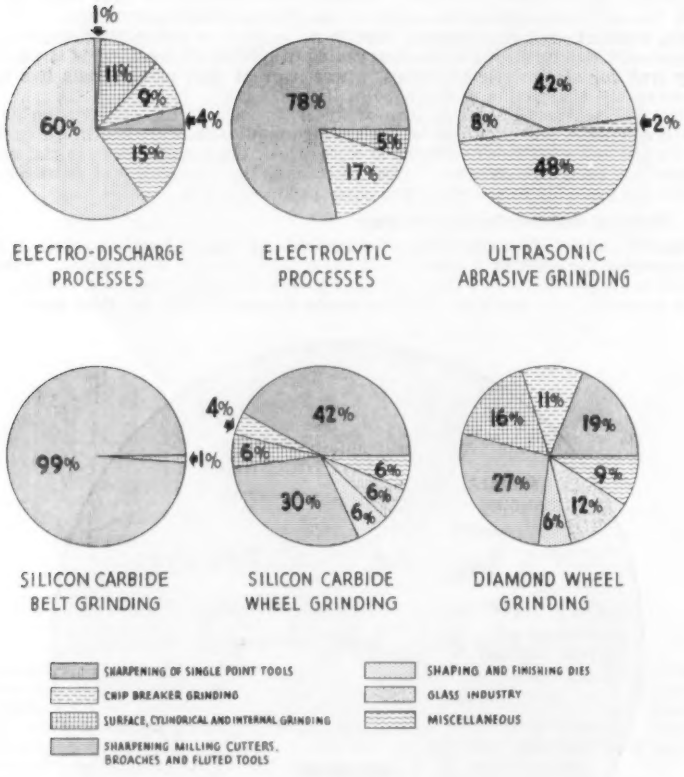

FIGURE 4

DISTRIBUTION OF RESEARCH and DEVELOPMENT EFFORTS FOR EACH PROCESS

(SEE APPENDIX II) 6/23/53

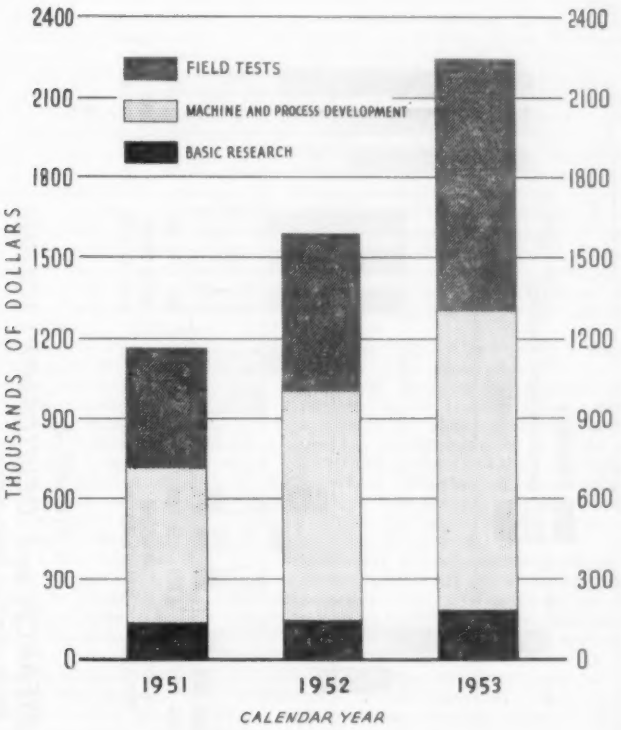

FIGURE 5

RESEARCH and DEVELOPMENT VOLUME FOR ALL NEW PROCESSES

(SEE APPENDIX II)

5/13/53

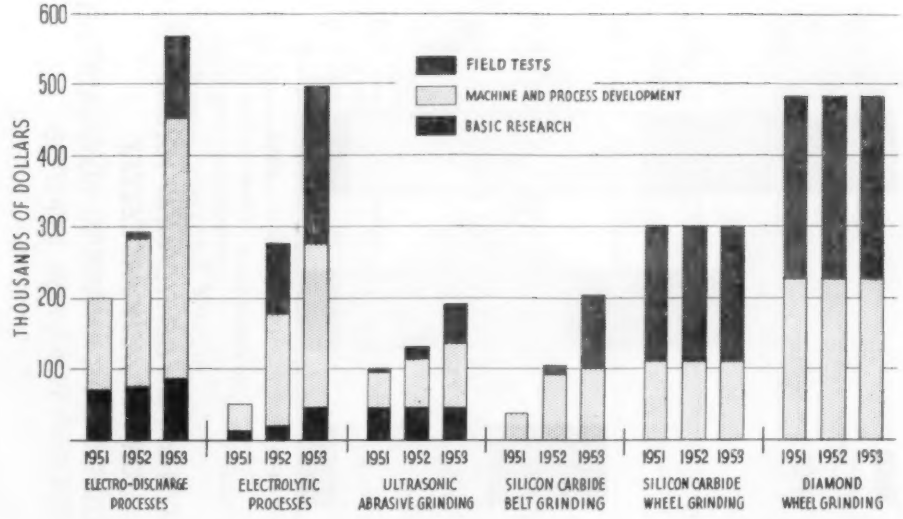

FIGURE 6

RESEARCH and DEVELOPMENT VOLUME FOR EACH PROCESS (SEE APPENDIX II)

6/23/53

Figure 5 summarizes the research and development volume for all six processes. These data indicate that an annual volume of over $2 million is currently being spent in research and development. Furthermore, overall research and development volume has approximately doubled in the last couple of years. The most marked increases in research and development have been in the areas of field tests and machine and process developments. Basic research also increased but not nearly so much as in the other two areas.

From the data shown in figure 6, it is evident that research and development on silicon carbide-wheel grinding and diamond-wheel grinding have not been increased over the past few years. Developments of both these processes have been going on for a number of years, and the most significant developments in recent years have been on more efficient use of wheels. For example, the so-called plunge-cut method, using narrow-width diamond-grinding wheels to machine cut, with one pass, as deep as 0.1 inch, appears promising for conservation of diamond bort, and much more research and development work can be done on this technique to improve and extend its applications. Other developments in the use of diamond-grinding wheels include the more extensive and intelligent application of coolants. Developments in improving the diamond wheel itself have been accomplished mostly through the development of superior bonds and by methods for inserting grains. An excellent example of the development of superior bonds is that of the vitrified bond for diamond wheels, with that product fully proven in the field. The development of the so-called single-layer diamond wheel has yet to be fully proven in the field. Continued developments along these and other lines will considerably stretch the available supply of diamond bort.

Silicon carbide-wheel grinding developments over the past several years have been principally improvements in the bonds. The more extensive use of the green silicon carbide grain has also been a significant step for improved grinding of cemented carbides. Some development efforts are currently being placed on applications of silicon carbide grinding wheels for sharpening milling cutters, broaches, and fluted tools. Another direction of development is in the area of new techniques in applying coolants. An example of this is the technique where the coolant is passed through a porous wheel. Further developments of improved bonds, use of coolants or lubricants, and techniques in the use of silicon carbide wheels will undoubtedly increase the application of silicon carbide wheels for operations where diamond bort is currently being used.

Silicon carbide-belt grinding has been recently introduced for finishing single-point tools. Figure 6 (for silicon carbide-belt grinding) shows a very high rate of increase in research and development since 1951, with most of the increase in the field-test aren.[4] Improvements in grains, bonds, machines, and techniques in its use are indicated as the areas of most profitable research for further development of silicon carbide-belt grinding.

Ultrasonic abrasive-grinding processes have experienced appreciable increase in research and development, particularly in the field-test area. Continued development work is being extended with emphasis on applications or field tests.

Electrolytic processes have experienced the most phenomenal rate of increase in research and development efforts over the past few years in this country. For example, figure 6 (for electrolytic processes) indicates that there has been approximately a tenfold increase in research and development volume since 1951. From this viewpoint, it can be considered as a baby just growing up, inasmuch as it is probably the newest of all six processes under consideration. Most of the emphasis in research and development on electrolytic processes has been in the areas of machine development and field tests. Field tests have emphasized sharpening of single-point tools, and results thus far appear very encouraging, particularly in that considerable savings of diamond bort for this application are indicated. Although metal-bonded diamond wheels are still being used with electrolysis, savings ranging from 60 to 95 percent of diamond bort for this application might be realized. Electrolytes, consisting of sodium nitrite-sodium nitrate types, have been principally studied, with some work on sodium silicates. Also, methods of introducing the electrolytes have been improved. Another area of research and development has been in electronics, for developing rectified power units to minimize acing and to extend the use to much higher current densities. Continued efforts along these general routes will undoubtedly provide marked improvements in electrolytic processes.

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[4] Silicon carbide belt grinding is being used extensively in the glass industry and fig. 4 does not properly reflect this activity.

According to figure 6, current research and development volume on electrodischarge processes is higher than on any other class of process. Most of the development work has been in machine developments and field tests since 1951. However, application developments have not emphasized those operations accounting for the greater part of diamond-bort consumption. Instead, they are being applied to operations where they are peculiarly adaptable, such as in shaping and finishing dies and miscellaneous operations (see fig. 4). A great deal has yet to be done in application to those other operations where relatively large quantities of diamond bort are being currently consumed. Recent significant developments have been in improving the quality of finish, compatible with high rates of stock removal. Progress has been made in improved circuits, servomechanisms, and precision. Further developments in these directions, and engineering for reduction of cost of the machines appear to be most pertinent.

5. CURRENT STATUS OF NEW PROCESSES

During the past year and a half, since the writing of report No. MAB–18–M, machines based on the new processes have been undergoing field tests and have been used in limited production. At the same time, continued and more intensive efforts have been made in experimental work in machine and process developments, particularly for new applications. However, the quantity of diamond bort conserved thus far by the use of new processes has been limited; but we might be on the threshold of rapid commercialization of new machining and grinding processes. Although intensive work is going on in the field to prove the practicability of new processes, good quantitative data as to performance in the field are lacking. This is not because of the number of field tests under way, but from the inherent difficulties encountered in obtaining reliable and reproducible information in production shops. Therefore, it is rather difficult to evaluate, at this time, the economics, performance, and trade acceptance. Nevertheless, the following sections attempt to present a qualitative picture of the status of new processes in these respects.

5.1 Development status of new processes

The development status of each new process for the seven selected applications or operations are shown qualitatively in table 1. If a process is currently accepted as a production tool for at least part of the operation indicated, it is assigned class A. Where a limited number of machines are now in shops, but if the shops have not as yet fully accepted them for a specific application, the process is class B. The experimental classification, class C, indicates that there has been an appreciable amount of experimental work for a process on a specific application or operation, but machines are not as yet available in the field. Blank spaces in table 1 indicate that no appreciable amount of experimental work has been accomplished for a class of process relative to a particular application.

Diamond-wheel grinding, of course, is in full production use on all the selected applications, because this is the basis for selection of the applications. However, new types of wheels and new techniques for the use of diamond-wheel grinding may not be in full production use. The plungs cut method is now in full production use for grinding chip breakers and the sharpening of milling cutters, broaches, and fluted tools, but not as yet for the other applications. Single-layer diamond wheels are now undergoing field tests for finishing single-point tools, where fine size diamond powder is used. This type of wheel cannot as yet be considered in class A. Other types of techniques in the use of grinding wheels, such as the use of coolants, are undergoing field tests.

Silicon carbide wheel grinding is limited to applications where the volume of grain in the wheel is high compared to the area of work being ground. Over the past year and a half it has been used a great deal for roughing operations on single point tools as encouraged by NPA Order M–103. The introduction of silicon carbide wheel grinding to a new application is probably much easier to attain than that of some of the other new processes because of its ready trade acceptance. Grinding relatively small areas of cemented carbides with a narrow, small-diameter silicon carbide wheel is not promising because of the relatively high wheel wear. This is why it may not find production use for grinding chip breakers. Other applications are limited to economic factors, wheel wear considerations, and limitations on precision and finish.

During the past year, more than 300 silicon carbide belt grinding machines were placed in production shops for finishing cemented carbide single-point tools,

and it is expected that at least a few hundred more will be used in the near future. However, silicon carbide belt grinding technique is limited to performing the final finishing operation on single-point tools for small areas of grinding, and silicon carbide wheel grinding is usually used alongside belt grinding for the roughing operation. Belt grinding should not be used for removing large amounts of stock in sharpening single-point tools. Sufficient quantitative data on economics and performance in field tests are not available to fully evaluate the merits of silicon carbide belt grinding. However, if production shops continue to accept belt grinding and use it properly, it will be a factor in the conservation of diamond bort.

TABLE 1.—*Development status for each process according to applications or operations*

[Code on status: A—Full production use; B—Limited production use, field tests; C—Experimental]

Applications or operations	Class of process					
	Electro-discharge	Electro-lytic	Ultra-sonic abrasive	Silicon carbide belt	Silicon carbide wheel	Diamond wheel
Sharpening of single-point tools [1]	C	B	C	A	A	A
Chipbreaker grinding (cemented carbides)	C	B	C	----	C	A
Surface, cylindrical, and internal grinding [2]	C	C	----	----	A	A
Sharpening milling cutters, broaches, and fluted tools (cemented carbides)	C	----	----	----	A	A
Shaping and finishing dies [3]	A	----	A	----	A	A
Glass industry grinding operations	----	----	B	A	A	A
Miscellaneous [4]	C	----	A	----	A	A

[1] Cemented carbides—offhand or machine grinding.
[2] Cemented carbides—including grinding of cemented carbide projectile cores.
[3] E. g., wire drawing, punching and blanking dies (cemented carbides and diamonds).
[4] E. g., sawing of concrete, stone, quartz, etc.; diamond drilling, gem stone cutting and polishing, polishing of jewel bearings, and other miscellaneous operations.

Approximately three times as many ultrasonic abrasive grinding machines as in 1951 are now in shops. These machines are in full production use or undergoing field tests for those applications or operations where they are finding natural and easy use. For some applications there is no better way to accomplish the job. As can be expected, most of these operations fall into a miscellaneous class. (See fig. 4.) Some advances have been made in experimental work on sharpening single-point tools and grinding chip breakers, but these have not moved in to field tests. If larger volume and more quantitative application development work were undertaken, the ultrasonic technique would probably find its place in more applications where diamond bort is currently being consumed.

As compared to a year and a half ago, the electrolytic process has moved very rapidly with respect to providing or converting machines for field tests. Currently, there are many machines in the field for sharpening single-point tools and chip breaker grinding. This technique is no longer experimental for these applications and the process could move rapidly into production. The developments and experience gained on sharpening single-point tools will be useful in the sharpening of milling cutters, and this may very well be the operation to which electrolytic processes will be applied next. Also, other operations involving the shaping and finishing of cemented carbides or other hard-to-machine metals might utilize electrolytic processes. From the diamond bort conservation viewpoint, electrolytic processes offer considerable promise to relieve the critical condition of supply and demand of bort in the near future. However, as for some of the other processes, developments are handicapped by lack of adequate field test facilities in industry.

The experimental application of electrodischarge processes has been extended to many operations over the past 18 months. Since it is peculiarly adapted for drilling small, deep holes and for complicated shapes, developments are emphasized for operations most suitable for the machines. Considerable experimental development work is currently progressing on the use of electrodischarge techniques for shaping and finishing hard-to-machine, high-temperature materials contemplated for jet engine components. Although diamond bort is not

now being used for this purpose, it is an important application for future diamond bort conservation, because if these techniques prove successful it will not be necessary to consider the use of diamond bort.

5.2 Economics and performance

As already mentioned, data on economics and performance have necessarily come from field tests or production shops, and adequate industrial facilities for obtaining quantitative data of this sort are very much deficient. However, it is feasible to assign a broad qualitative range on various items dealing with economics and performance for each of the new processes. Table 2 indicates the current cost and performance ranges for each class of process.

Initial capital cost is more important to the small shop than the large shop, but for many operations direct labor is probably the most important cost factor. Table 2 does not attempt to weight the various items in cost because they vary considerably with specific applications. Electrical power cost is the smallest item. Supplies include all consumable items, such as, wheels, coolants, electrolytes, tools, electrodes, etc.

The items under performance in table 2 refer to performance of the machines for removing stock and not performance of the as-shaped and finished pieces. Some of these items reflect themselves in economics. For example, rate of cutting partly determines direct labor costs; and checking and cracking will also have a bearing on economics in the sense that high risk of checking and cracking will cause more rejects. Other items, such as finish, precision, etc., contribute toward the quality and value of the article being shaped and/or finished. However, some finished articles are acceptable without high finish or precision and the evaluations in table 2 are not intended to eliminate specific applications.

5.3 Availability and trade acceptance

One of the primary considerations covered herein is the possible impact of new processes for machining and grinding on the conservation of diamond bort. In table 3 each of the six processes are qualitatively graded with respect to their requirements on the use of diamond bort. Of course, diamond wheel grinding is graded "poor" and those that use no diamond bort are graded "good." Electrolytic processes, as currently developed, still require the use of some diamond bort and they are often referred to as "electrolytically assisted diamond wheel grinding." However, the gradings in table 3 are not to be construed as the magnitude of diamond bort conservation in the near future. Actually, electrolytic processes may well conserve more carats of diamond bort than any of the other processes because they are being developed for operations where diamond bort is currently being consumed in large quantities.

Availability of machines is shown in table 3 by those in the field and those planned for production by the end of this year (1953). Also evaluated is the speed of converting existing conventional machines.

TABLE 2.—*Cost and performance ranges of new processes* [1]

Cost or performance item	Class of process					
	Electro-discharge	Electro-lytic	Ultra-sonic abrasive	Silicon carbide belt	Silicon carbide wheel	Diamond wheel
Costs:						
Initial capital cost [2]	High	Med.	High	Low	Low	Low.
Supplies	L-M	Low	L-M	L-H	M-H	M-H.
Direct labor	Low	Low	Low	L-M	L-M	Low.
Maintenance	L-M	L-M	L-M	Low	Low	Low.
Power (electrical) [2]	L-H	L-M	L-H	Low	Low	Low.
Performance:						
Finish (rms) [4]	P-G	F-G	P-G	F-G	F-G	F-G.
Precision	P-G	F-G	P-G	Fair	Fair	Good.
Rate of cutting	L-H	High	L-M	L-H	L-H	High.
Versatility [5]	Fair	Good	Fair	Poor	Good	Good.
Automatic operation [6]	High	L-M	M-H	Low	Low	Med.
Operator skill	L-M	Med.	L-M	Low	L-H	L-H.
Checking and cracking [7]	L-H	Low	Low	Low	M-H	Med.
Edge quality [8]	P-G	F-G	P-G	Fair	Fair	Good.

[1] Wherever range is shown reference is to different applications: P—poor; F—fair; G—good; L—low; M—medium; H—high.
[2] High—greater than $5,000 per machine; Med. (medium)—$1,500 to $5,000 per machine; Low—less than $1,500 per machine.
[3] High—more than 3 times conventional wheel grinding; Med. (medium)—2 to 3 times more than conventional wheel grinding; Low—same range as conventional wheel grinders.
[4] (Rms—root mean square roughness in microinches as measured by a profilometer.) Good—less than 10 rms; Fair—10 to 25 rms; Poor—greater than 25 rms.
[5] Versatility refers to ease of adapting same setup to different types of operations.
[6] A process rated "low" for automatic operation requires more attention of an operator.
[7] High—high risk of checking and cracking; Med. (medium)—moderate risk; Low—low risk.
[8] References are to sharpness of edge in tools rather than actual performance.

TABLE 3.—*Evaluation of diamond bort conservation, availability and trade acceptance for each new process* [1]

Items	Class of process					
	Electro-discharge	Electro-lytic	Ultra-sonic abrasive	Silicon carbide belt	Silicon carbide wheel	Diamond wheel
Diamond bort conservation [2]	Good	F-G	Good	Good	Good	Poor.
Availability:						
Machines in field [3]	Low	Low	Low	Med.	High	High.
Planned production [3]	Med.	L-M	Low	High	High	High.
Speed of conversion	Poor	Fair	Poor	Good	Good	
Trade acceptance:						
Appearance of finish	Fair	Fair	Fair	Fair	Fair	Good.
Safety	Good	Good	Good	Good	Good	Good.
Health	F-G	F-G	Good	Good	F-G	Good.
Operator convenience	Good	P-F	Good	Fair	Fair	Fair.
Training required	Med.	Med.	Med.	Low	Med.	Med.
Accessories	High	Med.	High	Low	Low	Low.

[1] Dependent on specific applications; ranges imply considerable differences dependent on the type operation.
[2] Where no diamond bort is required rating is good; in the case of electrolytic processes, the diamond wheels are still required but not near so much as for conventional diamond wheel grinding.
[3] High—more than 1,000 machines; medium—100–1,000 machines; low—less than 100 machines.

Trade acceptance of new processes in some instances is more of a bottleneck than the lack of technical developments. Industry is naturally reluctant to accept a new process until it has been fully proven in the shops and this takes time. Naturally, there is greater acceptance of machines that are only minor modifications of existing machines and this points up the ready trade acceptance of silicon carbide belt grinding and silicon carbide wheel grinding. Those processes that require major modifications in equipment or accessories or that result in considerable operator inconvenience, are handicapped in trade acceptance and must show advantages beyond small gains before they are readily accepted. Most of the items shown in table 3, under trade acceptance, are in-

fluenced a great deal by educational programs rather than research and development or technological developments.

5.4 Applicability of processes

A general picture of the technical applicability of each of the six processes is shown in table 4. The items listed are related but not identical to the operations shown in figures 2, 3, and 4. Table 4 shows clearly that some of the new processes have definite advantages over diamond-wheel grinding. Also, for drilling of small diameter deep holes, embossing, and tapping operations, the electro-discharge and the ultrasonic processes can perform where diamond-wheel grinding cannot. However, other procedures utilizing diamond bort are employed for these purposes.

TABLE 4.—*Applicability of processes* [1]

Machining and grinding operation	Class of process					
	Electro-discharge	Electro-lytic	Ultra-sonic abrasive	Silicon carbide belt	Silicon carbide wheel	Diamond wheel
Cemented carbides	Yes	Yes	Yes	Yes	Yes	Yes.
Metals (e. g., steel)	Yes	Yes	Yes	Yes	Yes	No.
Nonmetals	No	No	Yes	Yes	Yes	Yes.
Large areas [2]	Yes	Yes	No	Yes	(?)	Yes.
Small areas [3]	Yes	Yes	Yes	Yes	Yes	Yes.
Small diameter deep holes	Yes	No	Yes	No	No	No.[4]
Cutoff	Yes	Yes	Yes	No	Yes	Yes.
Embossing	Yes	No	Yes	No	No	No.
Offhand	(?)	Yes	(?)	Yes	Yes	Yes.
Fixed feed	Yes	Yes	Yes	Yes	Yes	Yes.
Form grinding	Yes	Yes	Yes	No	Yes	Yes.
Tapping	Yes	No	Yes	No	No	No.

[1] Code: Yes—means process is technically capable of machining and grinding those materials indicated and performing the other operations listed.
[2] Greater than 4 square inches.
[3] Less than 4 square inches.
[4] Loose diamond powder can be used for small-diameter deep holes, but not wheels.
[5] Recent developments indicate that offhand grinding by electro-discharge techniques is practical but it has not as yet been fully proven in the field.

The classifications in table 4 are not intended to show degree of effectiveness for the types of operations listed. That is to say, the question of economics and degree of performance were not considered in formulating this table. Wherever a question mark appears in the table, it is uncertain as to whether the particular process is technically feasible for the specific item listed.

6. CONCLUSION

In report No. MAB–18–M, several general conclusions were listed, with emphasis on the need for accelerating performance or field tests. Since this report was written, developments of new processes have extended into field tests and a great deal more information as to their merits is now available. Now, many new specific conclusions can be drawn, based on facts presented in the preceding sections. These new conclusions deal not only with research and development problems but also with production and some nontechnical problems.

6.1. Specific procedures for shops

In the event of an emergency, when the supply of diamond bort might not be sufficient to meet marked increased production, it would be very desirable to have specific procedures on hand covering preferred procedures on the use of new processes as alternates to diamond-wheel machining and grinding. However, technology and trade acceptance of new processes are currently moving so rapidly that any formulation of specific procedures would probably be obsolete upon issuance. Therefore, it is deemed inadvisable to formulate any specific preferred procedures relating to new processes in the event of an emergency at this stage. However, a mechanism for rapidly writing up these procedures at the beginning of an emergency should be set up so that they would be available without undue delay when they are seriously needed.

6.2 The large shop versus the small shop problem

Initial capital cost of some new processes may be prohibitive for the use of a small shop, even though it is economical for use in a large shop where production rates are much higher. Some of the new processes, such as new types of diamond-wheel grinding, silicon-carbide-wheel grinding, and silicon-carbide-belt grinding are less expensive from the viewpoint of initial capital cost, as compared to the other processes being developed. Even though, for some applications, these less expensive machines may not be so economical for high production rates per unit of finished article, they will probably find ready acceptance in the small shops, and further development of these less expensive machines should be encouraged. Use of these less expensive and most acceptable (trade acceptance) machines will probably be the most important factor in conserving diamond bort in the near future.

On the other hand, machines based on new principles, which are naturally more expensive per machine, have potentials that may not be realized by the more conventional and cheaper machines. These include machines based on electrodischarge, electrolytic, and ultrasonic techniques. The larger shops might realize advantages from these machines over more conventional types, which will overbalance initial capital cost and general trade acceptance. However, this will take a little time because it is recognized that the development of these newer processes is essentially still in its infancy. The small-shop problem is a very real and serious one, because there are so many of them and it would be well for organizations, developing new machines, to pay greater attention to simplification and reduction of initial cost.

6.3 Research and development problems

It was shown in figures 2 and 3 that distribution of research and development efforts on new processes is not entirely compatible with distribution of diamond bort consumption. More emphasis should be placed on those operations where diamond bort is being consumed heavily. For example, sharpening of milling cutters, broaches, and fluted tools, and surface, cylindrical, and internal grinding, accounts for approximately 44 percent of the diamond bort consumption, whereas research and development efforts spent for these operations amounts to only 16 percent of the total.

Volume of basic research efforts has not been so high as for machine and process developments, but it may be sufficient for industry's needs. Industry is currently sponsoring essentially all basic research programs on new processes, and feels that there is a sufficient volume in the area for its own information.

In machine and process developments (applied research), there is considerable activity in progress. However, considerable work has yet to be done in engineering and control for reduction of cost and for trade acceptance. It is expected that industry will continue its programs at a high level in this area with full recognition of the problems ahead.

The pattern of research and development of new processes for machining and grinding, from the stages of conception to production, is deficient in field tests or performance tests. After a machine is developed to the point where it is ready for field tests, it is often sent directly to a production shop for operation by production people. In this manner quantitative data are usually lacking and the machines are not always thoroughly tested. Furthermore, it is difficult for the organization developing machines to obtain the necessary facts from inadequate field tests to enable them to improve machines. It is necessary for machines to go into the field at rather early stages of their development, because of the specialized operations required. Performance tests of the machines for simple stock removal are usually not sufficient to evaluate a new process for a specific application. Not only is there deficiency in field test work on shaping and/or finishing pieces, but there are also inadequate facilities for performance tests on the pieces themselves.

Considering research and development work on all new processes collectively, it is evident that industry is spending fairly large sums of money without appreciable assistance from Government. Currently, over $2 million a year is being spent by industry and this will probably increase in the near future.

6.4 Availability of new processes in the event of emergency

Because new processes are still essentially in their infancies with respect to production use, they are not yet ready to take over a substantial portion of the operations normally using diamond bort. However, they are sufficiently

developed so that progress in industrial use should be very rapid following the first year of an all-out emergency.

Even without an all-out emergency, the new processes will continue to be developed and in time will find their places on a free economy basis. Nevertheless, there will always be a high demand for diamond bort which should consume all of the supply. If more time is allowed for development of new processes on a competitive level, this country will be in a much better position, when and if an all-out emergency occurs.

6.5 Acceptance of new processes

Trade acceptance of some new processes is a serious consideration. Of course, with further technological developments some new processes might be so attractive that the shops cannot afford to do without them. However, until this stage is reached, considerable education is needed for general trade acceptance. Considerable publicity has been given to new processes for machining and grinding over the past year in the technical and trade journals, and this has been helpful. However, it is necessary to have periodic publications of an unbiased nature, authored by technically capable people representing industry's and Government's interests as a whole. A few articles published in a prejudiced light can do a great deal of harm, or data presented from unreliable field tests can produce incorrect pictures. Most of the organizations developing new processes have sales engineers in the field, attempting to work closely with the ultimate users, but this effort should be supplemented with broader educational programs.

6.6 Industry's problems

From the facts presented in the preceding sections, it is evident that industry is able and willing to carry the responsibilities for developments of new processes for machining and grinding with a minimum of Government assistance. However, the one important area of development work which is not adequately covered by industry is field tests. Collective action on the part of industry to improve the situation is the one important step that can be taken to accelerate the proper production use of machines based on new processes.

Some individual organizations are now placing machines, based on new processes, in their production shops as a small fraction of their total machining and grinding equipment. It is admitted that this is being done principally as an insurance measure to obtain continued experience. Then if the need arises for shifting to a new process, those organizations who have had this experience will be in a very good position to make the shift quickly and efficiently. This is a very sound policy and more industrial organizations should be thinking in this direction.

7. RECOMMENDATIONS

Report MAB–18–M presented four recommendations relating to military activities, industrial research, educational programs, and liaison committee. Of these recommendations, the educational program was implemented to a much higher degree than the other three. Many technical and trade journals, the Office of Technical Information Services, Commerce Department, NPA, and industrial organizations published a great deal of information during the past year relating to new processes for machining and grinding.

At this writing, new recommendations are in order to supplement and/or revise those made a year and a half ago in report MAB–18–M. Based on the facts and conclusions presented herein, the following new recommendations are forwarded.

7.1 Industry should continue to carry the burden of responsibility in research and development of new processes for operations now requiring diamond bort

It has been shown that industry is willing and able to undertake research and development work required with a minimum of Government participation for those operations or applications normally performed by industry. This is a natural situation because industry has the real need for these new processes even though they are used, in part, in Government defense contracts.

7.2 Government should participate in research and development on new processes for shaping and finishing newly developed, essential military components which do not now use diamond bort

The processes now in prospect for machining hard materials will probably be adequate to meet any foreseeable demand. However, should new projected military requirements add materially to the demand for diamond bort, a simul-

taneous effort should be made to substitute the nondiamond machining and grinding processes. That is to say, the alternate processes should be given priority considerations for shaping and finishing components in new military equipment where diamond bort has not as yet been used. Shaping and finishing of hard-to-machine materials, such as alloys, metal ceramics, and cemented titanium carbide, to meet required specifications, would probably utilize new processes to advantage.

7.3 Individual shops should utilize machines based on new processes as an insurance measure

A few shops are already pursuing this policy and it should be extended, even though a new process may not be ready for full production use. By setting up 1 new machine in a group of say 20 conventional ones, an organization will gain operating experience and will be prepared to rapidly expand the use of these new machines in the event of serious diamond bort shortage. In addition, these organizations should attempt to obtain more quantitative and accurate field-test data to help themselves operate more efficiently and to assist the manufacturer of machines to improve on mechanical and electrical mechanisms.

7.4 An effective mechanism of periodic studying and reporting on new processes for machining and grinding should be set up

This is dictated by the recognition that all diamond bort available now and in the future will probably be completely utilized. Periodic reporting of facts, coupled with new conclusions and recommendations to industry and Government as a whole, will help steer the progress in development of new processes and the intelligent use of available diamond bort. The mechanism for accomplishing this can be handled through (*a*) collective sponsorship by industry; (*b*) Government sponsorship; (*c*) scientific societies; and/or (*d*) trade associations.

7.5 Proper educational programs should be continued

Only through the medium of widespread publications can the small shops throughout the country obtain reliable information easily. In addition to the normal articles contained in trade journals and technical publications, Government and industrial bulletins would be helpful. Also, the periodic type of reporting by an unbiased and technically capable group is a necessary part of the educational program.

7.6 Collective action by industry should be considered as a means of improving application developments

Developments relying on field tests are recognized as inadequate for sound and rapid advances in bringing new processes for machining and grinding into full production use. There is a great deal of unnecessary duplication of effort in industry on field tests which can be more profitably handled collectively. It is not the intent of this recommendation to propose elimination of the type of field test work normally undertaken now by industrial organizations, but it is recommended that supplementary facilities be set up to fill the gap between machine developments and ultimate use of machines. Industry can profit through collective action in this area providing the proper mechanism is established for handling the administration of such joint efforts. Any programs initiated under such a mechanism should only be those which are not in the proprietary information class and which will develop publishable results of use to industry as a whole. The administration of such collective action could best be handled through an existing or new trade association funded by industry members.

APPENDIX I

8. METHOD OF OBTAINING DATA ON DISTRIBUTION OF DIAMOND BORT CONSUMPTION

The data shown in figure 2, relating to percent use of diamond bort in machining and grinding operations, was compiled through special surveys conducted by a member of the task group and the National Production Authority.

Thirty listed manufacturers of diamond grinding wheels were asked to submit a report on the estimated diamond consumption, by percentage, for the seven diamond grinding categories shown in figure 2. Sixteen of these companies submitted reports showing percentage figures based on their own sales. Of those who did not report, most indicated that they were either no longer in the diamond wheel business or that their volume of business was so small as to be of no consequence in the survey. The information from the 16 report-

ing companies was submitted to the task group on a business-confidential basis, and, therefore, figures for each individual company cannot be published.

Of the 16 reporting companies, 4 were distributors only and were omitted from the final calculation to avoid duplication. The remaining 12 were then weighted in accordance with NPA's data on recent annual diamond bort consumption [1] and the overall weighted distribution was calculated. Further adjustments were made, using other NPA data, to account for essentially all of the diamond bort consumption in addition to that used in the grinding wheel industry.

The 12 reporting companies whose data were used for the calculations accounted for approximately 86 percent of total diamond bort consumption in diamond wheels and saws, or about 72 percent of total diamond bort consumption in this country. A listing of these 12 reporting companies is as follows:

A. I. T. Diamond Tool Co., Chicago, Ill.
Action Diamond Tool Co., Chicago, Ill.
Bay State Abrasive Products Co., Westboro, Mass.
The Carborundum Co., Niagara Falls, N. Y.
Diamond Tool Research Co., New York, N. Y.
Diamond Wheel Industries, Chicago, Ill.
Felker Manufacturing Co., Torrance, Calif.
Norton Co., Worcester, Mass.
Precision Diamond Tool Co., Elgin, Ill.
J. K. Smit & Sons, Inc., Murray Hill, N. J.
Super-Cut, Inc., Chicago, Ill.
The Wickman Manufacturing Co., Detroit, Mich.

[1] This calculation was performed by NPA without releasing data on individual company's consumption.

Appendix II

9. Survey of research and development activities

The information shown in figures 3, 4, 5, and 6 and in tables 1, 2, 3 and 4 was derived from a special survey conducted by the task group. Essentially all of the data were obtained through interviews with representatives of the organizations listed below:

Behr-Manning Co., Troy, N. Y.
Buick Division, General Motors Corp., Flint, Mich.
Carboloy Department, General Electric Co., Detroit, Mich.
Carborundum Co., Niagara Falls, N. Y.
Cavitron Equipment Co., Long Island City, N. Y.
Chrysler Corp., Detroit, Mich.
Cincinnati Milling Machine Co., Cincinnati, Ohio.
Elox Corp., Clauson, Mich.
Ex-Cell-O Corp., Detroit, Mich.
Fenlind Engineering Co., Rockford, Ill.
Firth Sterling Steel & Carbide Corp., (Method X), Pittsburgh, Pa.
Ford Motor Co., Detroit, Mich.
Frankford Arsenal, Philadelphia, Pa.
Hammond Machinery Builders, Inc., Kalamazoo, Mich.
Kennametal, Inc., Latrobe, Pa.
Minnesota Mining & Manufacturing Co., St. Paul, Minn.
Norton Co., Worcester, Mass.
Precision Diamond Tool Co., Elgin, Ill.
Raytheon, Inc., Waltham, Mass.
Super-Cut, Inc., Chicago, Ill.
Watertown Arsenal, Watertown, Mass.
Wickman Manufacturing Co., Detroit, Mich.

Appendix III

10. Partial list of publications [1]

1. Panel of the Minerals and Metals Advisory Board: New Processes for Machining and Grinding, Report MAB–18–M, January 18, 1952.[2]
2. New Processes Will Machine the Unmachinable, American Machinist, March 17, 1952.

[1] Articles referring to new processes for machining and grinding are supplementary to the report, and the material in the report was not derived from these publications. Articles listed herein consist of only recent selected publications; for a more complete bibliography refer to report MAB–18–M (No. 1 above).

[2] Report MAB–18–M may be obtained from the Library Section, Office of Technical Services, U. S. Department of Commerce, at a cost of $2.25 per copy, with checks made payable to "The Treasurer of the United States."

3. Elwers, George: Four Ways Around the Diamond Shortage—New Machining Techniques Evaluated, Iron Age, March 20, 1952.
4. Conserve Diamond Bort and Cut Hard-to-Machine Metals With New Machining Processes, Journal of Metals, April 1952.
5. Lennon, F. J.: An Evaluation of Diamond-Substitute Processes, Tooling and Production, February 1953.
6. Theory of Electric Spark Machining, Electrical Engineering, March 1952.
7. Armagnac, Alden P.: Electric Sparks Carve World's Hardest Metals, Popular Science, February 1952.
8. Storey, O. W.: Electrolytic Grinding or Machining of Metals, J. Electro-Chem. Soc., May 1953.
9. Thibault, N. W., and Anderson, B. H.: Electrolytic Grinding of Carbides Fully Tested, Iron Age, November 13, 1952.
10. Metzger, L. H. and Keeleric, George: Electrolytic Grinding, American Machinist, November 10, 1952.
11. Metzger, L. H.: Development in Electrolytic Grinding, ASTE, March 18, 1953.
12. Keeleric, George: Electrolytic Grinding, Steel, March 17, 1952.
13. DeGroat, George H.: Soft Steel and Ultrasonic Machine Carbides, American Machinist, September 15, 1952.
14. Department of Defense report: A Demonstration of Ultrasonic Process for Grinding and Machining Metals and Non-Metals, October 1952.
15. Ultrasonic Carving Machine, Life magazine, November 3, 1952.
16. Even a Key Can Cut Through the Un-Machinable With New Ultrasonic Tool, Inco magazine, vol. 26, No. 1, 1953.
17. Ultrasonic Machining of Carbide and Other Hard Materials, Tooling and Production, July 1953.
18. DeGroat, George H.: When Abrasive Belts Grind Carbide, American Machinist, December 8, 1952.
19. Silicon Carbide Wheels for Carbide Grinding, American Machinist, page 143, April 27, 1953.
20. Lennon, F. J.: Economic Factors Must Govern Wheel Selection for Grinding Carbides, American Machinist, February 16, 1953.
21. Taeyaerts, Jan: Diamond Wheel Life Extended by Plunge Cut Grinding of Carbides, Tooling and Production, October 1952.

AFTER RECESS

Senator MALONE. The committee will be in order.

Mr. A. D. Leveridge, of New York, Industrial Diamond Association, will be the first witness.

Mr. Leveridge, do you have a prepared statement?

STATEMENT OF ATHOS D. LEVERIDGE, EXECUTIVE MANAGER AND SECRETARY-TREASURER, INDUSTRIAL DIAMOND ASSOCIATION OF AMERICA, INC., NEW YORK, N. Y.

Mr. LEVERIDGE. I have, Senator. I would like to read my statement to you, if I might. There is one privilege I would like to ask, if you please. I have been ill, and last week when it was called off I decided to go down—and I have decided to go down—and have left my wife half way south with the car. The only way to get there would be by plane, leaving here at 5:03. If I might be permitted to read this to you and then reappear for any questions that you would like, sometime in the future.

Senator MALONE. Certainly. You have listened to our hearings. All we want is the best information we can get in these particular matters.

Mr. LEVERIDGE. I appreciate that, sir, and I very much enjoyed your work this morning.

I am Athos D. Leveridge, executive manager, Industrial Diamond Association of America, Inc., of New York City. The following statement is made on behalf of many members who have become aware of the committee hearing and who desire that their opinions be expressed to you. As the membership in general was not posted on the scope of your proceedings, they were not in a position to express themselves. Therefore, although it is believed that all firms in the association are in complete accord as to the facts and arguments presented, this statement is not presented as an official document of my association but as an expression of the views of many of its members.

Senator MALONE. This Industrial Diamond Association includes the producers?

Mr. LEVERIDGE. No; the importers and dealers of industrial diamonds, loose, and the manufacturers of the diamond tools and products which contain the raw materials. They distribute it to the different companies.

Senator MALONE. How many firms or companies do you have?

Mr. LEVERIDGE. At this time I believe there are 65 firms.

Senator MALONE. It might be a good idea if, in your own time, you could furnish us a list of the membership.

Mr. LEVERIDGE. I shall furnish that to you now, sir. I will leave that with the gentlemen here.

Senator MALONE. That will be inserted into the record at this point.

(The material referred to follows:)

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NEW YORK, N. Y., JULY 1, 1954

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I. J. Meade, 1949
Frank E. Koebel, 1950
James A. Ross, 1951
Harold E. Robison, 1952
William F. Mullins, 1953
Executive manager, Athos D. Leveridge
Legal counsel, Meyer Boskey
Certified public accountants, Apfel & Englander

[Name of firm's official representative for I. D. A. appears in italic]

A

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Cochaud Wire Die Corp., *Mr. Fernand Durand*, 300 West 56th Street, New York
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Mr. LEVERIDGE. So that the committee may evaluate the source of the main points of this short statement, we inform the Senators of the origin and purpose of the Industrial Diamond Association of America and such of its activities as may be germane to the present proceedings. The IDA was organized 9 years ago by a group of industry leaders as a result of the observation and experience of themselves and of World War II War Production Board officials. They felt that such an institution was needed for the coordination of such forward-looking activities as a trade association might properly concern itself with, in the interests of the group and in the public interest, which includes maintenance of a healthy condition in an essential industry. Ever since, this association has been called upon by the various branches of government and by American industry in general for advice and cooperation. These have been freely given at all times.

The results were successful, as the Industrial Diamond Association includes in its membership a large majority of the American firms which produce a deal exclusively in diamond tools and diamond products, and therefore are considered to be the experts of their field. The Government has expressed high appreciation.

INDUSTRIAL DIAMOND SUPPLY DURING KOREAN EMERGENCY

Notable amongst innumerable instances of assistance from the members of the association and its officers in a time of national emergency, was the manner in which the Government's hands were upheld in its efforts to bring order into a confused situation on diamond supply during the Korean events. Panels of experts were supplied by us when there were being formulated regulations whose provisions could be expected to bring compliance from industry's men and practical results. They succeeded.

At the outset of Korea, with huge Government contracts to be distributed to manufacturers of automotive, aeronautical, and other important military material, each manufacturer took immediate steps to try to insure for itself an abundant supply of equipment and tools. A rush on the producers of diamond tools was a natural corollary. Usual sources of diamond-tool supply were receiving avalanches of unusual orders, and a manufacturer would duplicate his order almost wherever orders were being taken—I might add, even where people had not produced the materials before. In their turn, the manufacturers of diamond tools—mostly grinding wheels—rushed to obtain supplies of diamond powder and of the crushing boart type of indus-

trial diamond from which is crushed the powder ingredient of diamond grinding wheels.

The National Production Authority's Miscellaneous Metals and Minerals Division was besieged from all sides with pleas for assistance in obtaining diamond boart and powder. It was difficult, if not impossible, to evaluate the actual requirements. To the observer without a good, overall picture of the industrial diamond industry, there thus appeared to be a critical shortage. But there was not any shortage.

The executive manager of this association and various of its members, when called for conference or by their own initiative, were able to convince the Government that if it could know where to locate all of the raw commodity, and influence its acquisition and sale, and that if those who used diamond grinding wheels in industry were prohibited from ordering more than their reasonable advance requirements, the shortage bubble would burst.

The National Production Authority by its Order M–102 sponsored by the NPA Miscellaneous Metals and Minerals Division, and Order M–103 sponsored by NPA Metal Working Division, both issued March 13, 1952, reflected the results of this close cooperation. Within months the pressure was relieved, and of actually required supplies, only those backlogs of orders existed which are to be found at normal times in every active industry.

After any cure is effected, the fear and the memory often linger, particularly in those who were not associated in formulating the remedies; they fear that they would not know what to do in some future recurrence of a serious situation. Many ambitious and sometimes ingenious imaginations are fired. Often this is well for the sake of progress. But it became necessary on more than one occasion for members of this association to recite the above story in official quarters and ask that actual facts be obtained before serious steps were taken. Otherwise, a great waste of time and money might be incurred through sponsorship of research for substitutes which would not be needed, even if they were to exist. Whenever these facts have been set forth and reference material supplied for verification, reason has prevailed. Government has not interfered, and industry, in the American way, continues its progress in its own best lights.

PRESENT INDUSTRIAL DIAMOND SITUATION

This statement on the present situation is made as a result of studies and analyses of reports. Some 2 or 3 of the many substitute methods for machining of the hard metals, carbides, et cetera, can be used effectively, within limits, in certain partial phases of mechanical production. Improvement in these processes can be expected. But much of the processing that has required industrial diamonds will continue to require industrial diamonds, always the most efficient, most economical medium for such operations. At best, substitute methods still would be substitutes, costly to use.

The use of the above recently developed supplementary aid to production, together with the Government stockpile, and a supply of industrial diamonds and tools always in the hands of the various branches of the industry, would provide all American industry requirements for a long period. It then only would be necesary in a time of national emergency, quickly to resume the same moderate controls

as were established by NPA. Orders M–102 and M–103 during Korea, when not one wheel in industry failed to turn for lack of industrial diamonds. Lacking precise information on the contents of the strategic stockpile, it is not possible for us to suggest for how many years provision thus is made. It is a recognized fact that huge acquisitions have been made, are being made, and should continue to be made, which would create a sufficient cushion for a great many years.

In addition to the above, it appears advisable again to add that this association and its members constantly are working to inform users of industrial diamonds in methods which prolong the life of diamond tools: that diamond-tools' producers, like other modern American manufacturers, continue to make their products more efficient and more durable, hence more economical to use. It is reasonable to expect that these constructive activities will continue progressively, and the same with reclamation of diamond material from used tools, which salvaging has increased many times since Korea, spurred on by the fair competition which is a tradition of American business. These and the longer processing life for diamond tools and products are tantamount to stretching the supply even beyond the safety limits which already will have been pushed back, in times of emergency, by the methods described in the previous paragraphs.

In peacetime we have an enormous problem in distribution, not being able to dispose of all the industrial diamonds which our distributors import from abroad. Were this Senate committee to recommend, and the Government to institute research projects for substitutes with which to eliminate industrial diamond, an unjust, a vital, and an unnecessary blow would be struck at this strategic industry. Confidence in the assurance that industrial diamonds are here to stay would be shaken. Users might be misled into failing to maintain their plants as to diamond-using machinery, and not acquiring the latest, more efficient, modern equipment. Then the industrial-diamond importers, who already have a serious and complicated merchandising problem, might no longer carry the burden of inventories that are necessary if each manufacturer is to obtain his highly specialized diamond requirements.

It appears necessary at this time for members and officers of this association, as they have done with other high authorities as cited above, to advise the Senate's Minerals, Materials, and Fuels Economic Subcommittee not only of the above situation wherein an artificial shortage was created, but also of the ways and means by which, with our assistance, Government was enabled to obtain the true facts, to put an end to the unjustified rush for diamonds, and consequently to end the false symptoms of shortage. This is necessary because we have an industry of utmost value in peacetime, and critical value in time of war. It should not be injured if the public interest is to be served.

If confidence in industrial diamonds is undermined through an organized and widely bruited drive to try to eliminate them, such an effort would defeat its own well-intentioned purposes and result in damage to defense aims.

That is our case, Mr. Chairman.

Senator MALONE. I think you made a very fine statement. You see, the only concern of the committee is that there be no shortage in time of war.

Mr. LEVERIDGE. I appreciate that.

MEASURES TO ASSURE SUPPLY OF INDUSTRIAL DIAMONDS DURING EMERGENCY

Senator MALONE. And to assure the security of this Nation. If I get the purport of your argument, it is not your contention that you can produce the diamonds you need in this hemisphere, but that with proper attention, regardless of the source, there is always a backlog and none of the industrialists concerned with producing tools for this industry or in industry itself can carry over any——

Mr. LEVERIDGE. Plus the stockpile, of course.

Senator MALONE. Reasonable emergency plus a reasonable stockpile.

Mr. LEVERIDGE. Yes.

Senator MALONE. Do you have any knowledge of the possibility of increased production in the hemisphere, like in Brazil or other places?

Mr. LEVERIDGE. I do not think that offers very much hope, sir. The inaccessibility of the sources of these diamonds is such that we might not overcome that for many years to come, within our time.

Senator MALONE. We have had testimony that there are sources that could be developed; probably not all at once, but looking ahead. It is not the intention of this committee to upset any business.

Mr. LEVERIDGE. I realize that, sir.

Senator MALONE. But it is the intention of the committee to do just what we did do in this report, to determine just where we stand on the matter of national defense.

Mr. LEVERIDGE. Senator, I would like to thank you very much for your indulgence on this. You see, in writing this report we have been very close to this picture, and we are good Americans.

Senator MALONE. I am certain of that.

Mr. LEVERIDGE. We have been watching this same situation. We have been very close to the picture because of all the Government departments that were served in it. I trust that there might be some occasion when you might call me and question me in detail, should some points arise in this that will bring up questions.

Senator MALONE. I do not think they will. If they do, we will get in touch with you. Your testimony, as long as it is a written statement—unless you have something else to offer—you may complete it.

Mr. LEVERIDGE. I do not have anything further, Senator, but I am ready any time to substantiate it in any way.

Senator MALONE. What we need to know—and this is what we are inquiring into, and I do not know if you have kept abreast of it—is that testimony has been presented to this committee that in an emergency we could reduce the use of industrial diamonds by 50 percent.

Mr. LEVERIDGE. It could be reduced by a very material amount through some of these substitutes; not necessarily on the most important uses of the diamond, but at least taking up the slack where they could, even as a more costly process.

Senator MALONE. Of course, expense is not the controlling factor. What we want to be able to say is that we are able to fight in war or live in peace wifhout being under the blackmail, possibly, of other nations.

Mr. LEVERIDGE. We are a hundred percent with you, Senator.

Senator MALONE. I wonder if you could go into your various uses. You did not do it in your paper.

Mr. LEVERIDGE. Could I leave this with you, this pamphlet?

Senator MALONE. Yes. This covers it fully?

Mr. LEVERIDGE. Yes.

Senator MALONE. Is it covered in this material where the substitutes will work?

Mr. LEVERIDGE. No.

Senator MALONE. That is what we need.

Mr. LEVERIDGE. That is something we will be very glad to go into for you.

Senator MALONE. Will you do that? Suppose we return this to you. Your office is in New York?

Mr. LEVERIDGE. My office is in New York. I am not going there now, but I will be glad to take care of it.

Senator MALONE. When will you be back?

Mr. LEVERIDGE. In a week or 10 days.

Senator MALONE. That will be fine. Suppose we return it to you for your correction. Then will you include not only the uses of industrial diamonds in wartime and in general use——

Mr. LEVERIDGE. But our opinion on the substitutes?

Senator MALONE. But your opinion where substitutes will work satisfactorily without too much additional expense, and where they will work where it will entail additional expense, and where you think industrial diamonds are absolutely necessary.

Mr. LEVERIDGE. I will try to do so, sir. Thank you very much for your indulgence, Senator.

Senator MALONE. Thank you, and goodby.

(The material referred to is as follows:)

INDUSTRIAL DIAMOND ASSOCIATION OF AMERICA, INC.,
November 8, 1954.

MINERALS, MATERIALS, AND FUEL ECONOMICS SUBCOMMITTEE,
Committee of Interior and Insular Affairs,
United States Senate, Washington, D. C.

GENTLEMEN: 1. The following statement is made on behalf of many members who have become aware of the committee hearing and who desire that their opinions be expressed to you. As the membership in general was not posted on the scope of your proceedings, they were not in a position to express themselves. Therefore, although it is believed that all firms in the association are in complete accord as to the facts and arguments presented, this statement is not presented as an official document of my association, but as an expression of the views of many of its members.

2. So that the committee may evaluate the source of the main points of this short statement, we inform the Senators of the origin and purpose of the Industrial Diamond Association of America and such of its activities as may be germane to the present proceedings. The I. D. A. was organized 9 years ago by a group of industry leaders as a result of the observation and experience of themselves and of World War II War Production Board officials. They felt that such an institution was needed for the coordination of such forward-looking activities as a trade association might properly concern itself with in the interests of the group and in the public interest, which includes maintenance of a healthy condition in an essential industry. Ever since, this association has been called upon by the various branches of Government and by American industry in general for advice and cooperation. These have been freely given at all times.

3. The results were successful, as the Industrial Diamond Association includes in its membership a large majority of the American firms which produce or deal exclusively in diamond tools and diamond products, and therefore are considered to be the experts of their field. The Government has expressed high appreciation.

4. Notable amongst innumerable instances of assistance from the members of the association and its officers in a time of national emergency was the manner

in which the Government's hands where upheld in its efforts to bring order into a confused situation on diamond supply during the Korean events. Panels of experts were supplied by us when there were being formulated regulations whose provisions could be expected to bring compliance from industry's men and practical results. They succeeded.

5. At the outset of Korea, with huge Government contracts to be distributed to manufacturers of automotive, aeronautical, and other important military materiel, each manufacturer took immediate steps to try to insure for itself an abundant supply of equipment and tools. A rush on the producers of diamond tools was a natural corollary. Usual sources of diamond tool supply were receiving avalanches of unusual orders, and a manufacturer would duplicate his order almost wherever orders were being taken. In their turn, the manufacturers of diamond tools (mostly grinding wheels) rushed to obtain supplies of diamond powder and of the crushing boart type of industrial diamond from which is crushed the powder ingredient of diamond grinding wheels.

6. The National Production Authority's Miscellaneous Metals and Minerals Division was besieged from all sides with pleas for assistance in obtaining diamond boart and powder. It was difficult, if not impossible, to evaluate the actual requirements. To the observer without a good, overall picture of the industrial diamond industry, there thus appeared to be a critical shortage. But there was not any shortage.

7. The executive manager of this association and various of its members, when called for conference or by their own initiative, were able to convince the Government that if it could know where to locate all of the raw commodity, and influence its acquisition and sale, and that if those who used diamond grinding wheels in industry were prohibited from ordering more than their reasonable advance requirements, the shortage bubble would burst.

8. The National Production Authority by its Order M–102 sponsored by the NPA Miscellaneous Metals and Minerals Division, and Order M–103 sponsored by NPA Metal Working Division, both issued March 13, 1952, reflected the results of this close cooperation. Within months the pressure was relieved, and of actually required supplies only those backlogs of orders existed which are to be found at normal times in every active industry.

9. After any cure is effected, the fear and the memory often linger, particularly in those who were not associated in formulating the remedies: they fear that they would not know what to do in some future recurrence of a serious situation. Many ambitious and sometimes ingenious imaginations are fired. Often this is well for the sake of progress. But it became necessary on more than one occasion for members of this association to recite the above story in official quarters, and ask that actual facts be obtained before serious steps were taken. Otherwise, a great waste of time and money might be incurred through sponsorship of research for substitutes which would not be needed, even if they were to exist. Whenever these facts have been set forth and reference material supplied for verification, reason has prevailed. Government has not interfered, and industry, in the American way, continues its progress in its own best lights.

10. This statement on the present situation is made as a result of studies and analyses of reports. Some 2 or 3 of the many substitute methods for machining of the hard metals (carbides, etc.) can be used effectively, within limits, in certain partial phases of mechanical production. Improvement in these processes can be expected. But much of the processing that has required industrial diamonds will continue to require industrial diamonds, always the most efficient, most economical medium for such operations. At best, substitute methods still would be substitutes, costly to use.

11. The use of the above recently developed supplementary aid to production, together with the Government stockpile, and a supply of industrial diamonds and tools always in the hands of the various branches of the industry, would provide all American industry requirements for a long period. It then only would be necessary in a time of national emergency, quickly to resume the same moderate controls as were established by NPA Orders M–102 and M–103 during Korea, when not one wheel in industry failed to turn for lack of industrial diamonds. Lacking precise information on the contents of the strategic stockpile, it is not possible for us to suggest for how many years provision thus is made. It is a recognized fact that huge acquisitions have been made, are being made, and should continue to be made, which would create a sufficient cushion for a great many years.

12. In addition to the above, it appears advisable again to add that this association and its members constantly are working to inform users of industrial

diamonds in methods which prolong the life of diamond tools; that diamond tools' producers, like other modern American manufacturers, continue to make their products more efficient and more durable, hence more economical to use. It is reasonable to expect that these constructive activities will continue progressively, and the same with reclamation of diamond material from used tools, which salvaging has increased many times since Korea, spurred on by the fair competition which is a tradition of American business. These and the longer processing life for diamond tools and products are tantamount to stretching the supply even beyond the safety limits which already will have been pushed back, in times of emergency, by the methods described in the previous paragraphs.

13. In peacetime we have an enormous problem in distribution, not being able to dispose of all the industrial diamonds which our distributors import from abroad. Were this Senate committee to recommend, and the Government to institute, research projects for substitutes with which to eliminate industrial diamonds, an unjust, a vital, and an unnecessary blow would be struck at this strategic industry. Confidence in the assurance that industrial diamonds are here to stay would be shaken. Users might be misled into failing to maintain their plants as to diamond-using machinery, and not acquiring the latest, more efficient, modern equipment. Then the industrial diamond importers, who already have a serious and complicated merchandising problem, might no longer carry the burden of inventories that are necessary if each manufacturer is to obtain his highly specialized diamond requirements.

14. It appears necessary at this time for members and officers of this association, as they have done with other high authorities as cited above, to advise the Senate's Minerals, Materials and Fuels Economic Subcommittee not only of the above situation wherein an artificial shortage was created, but also of the ways and means by which, with our assistance, Government was enabled to obtain the true facts, to put an end to the unjustified rush for diamonds, and consequently to end the false symptoms of shortage. This is necessary because we have an industry of utmost value in peacetime, and critical value in time of war. It should not be injured if the public interest is to be served.

15. If confidence in industrial diamonds is undermined through an organized and widely bruited drive to try to eliminate them, such an effort would defeat its own well-intentioned purposes and result in damage to defense aims.

Sincerely,

ATHOS D. LEVERIDGE.
Executive Manager.

ADDENDUM AS REQUESTED BY SENATOR MALONE AT THE WASHINGTON HEARING ON NOVEMBER 17, 1954, TO BE INCLUDED AS A PART OF THE STATEMENT THAT WAS READ ON BEHALF OF INDUSTRIAL DIAMOND INDUSTRY MEN AT THE HEARING

Since writing the foregoing statement, there was long personal consultation with many leaders of the industry and experts in the technical and economic aspects of the industrial diamond industry, in many cities.

Amongst these, were manufacturers of diamond tools and products and suppliers of industrial diamonds. Also, the World War II Chief of WPB's Industrial Diamond Section who, for decades, has been one of the members of the industry and is a member of the Industrial Diamond Association of America. Furthermore, the writer of this statement, now the association's executive manager, was Chief of a War Production Board section assigned to resolve one of the important production, distribution, and allocation problems of industrial diamonds in World War II.

These men all have been close to the diamond conservation picture as well, having participated in, or contributed to such activities through the IDA. With the United States Department of Commerce, the association cosponsored the diamond material salvage and conservation clinics during Korea in various production centers of the United States of America and worked in them. Also in publishing and circulating educational material for reclamation and for the most efficient and economical use of diamond wheels, diamond tools, and products.

It is therefore believed that not only the foregoing statement made at the hearing, which has required no change, but also this addendum to cover the additional points desired to be covered by Senator Malone, is entirely factual, and that the opinions can be considered as the best to be obtained on industrial diamonds in America.

Below are the uses or applications which account for the consumption of over 99 percent of industrial diamonds and an opinion as to the amount or degree in which each of these processes of diamonds can be substituted for with other materials or processing methods.

Applications No. 1—Diamond grinding of sintered carbide consumes some 60 to 70 percent of all industrial diamonds.—This requires only the cheapest grade, which is known as crushing boart. The crushing boart is reduced to diamond powder and bonded into grinding wheels. Of this low grade (crushing boart) some 80 percent is used in above wheels.

The lowest grade of "dressing diamonds," in an emergency, also could be crushed into powder and utilized for carbide grinding at less than double the per carat price of crushing bort. Usually there are more low grade diamond dressing tool stones imported than find a ready market, even in times of national emergency.

It is our opinion that some 50 percent of the sintered carbide tool sharpening processes which absorb the greatest quantity of all industrial diamonds, could be substituted for with silicon carbide or electric and electrolytic devices, in some cases at a greater cost in money and man-hours, but not prohibitive in cost for a time of national emergency. The remainder of the processes belong in the diamond field so firmly, that it is not believed the precision work with fine tolerances and the economy of their use can be substituted for.

We have excerpts from statements received from foremost members of the industry to whom we applied for precise opinions so that we might be certain that our opinions here expressed will be well founded. From the outstanding specialists of one of the largest producers of industrial diamond tools and products in the world, we quote the following, concerning substitution in the case of sintered carbide tool grinding:

"Silicon carbide as a substitute never was a serious factor and to date is not.

"The processes employing electricity by one of several methods have been known for some time. Published information dating back to 1946 is available and known to the Department of Defense, National Academy of Sciences, and others indicating that considerable work has already been done and is in progress at this time. This work has been done by American industry on a competitive basis. If these electrical substitute processes are a potential replacement for conventional diamond wheels, American industry will find a way to accomplish this * * *."

Also

"One most important fact also must be brought to the attention of the Senate Investigating Committee. Up to a few years ago the resinoid bonded diamond wheel was in greatest demand. Metal bonded and vitrified bonded diamond wheels were available at that time but were not widely used because industry was not acquainted with their greater efficiency. Korea, which caused a false shortage, brought about Government regulations sponsored by the diamond industry. Due to these regulations, the long life characteristics of vitrified and metal bonded wheels were vividly brought to the attention of American industry. It is well known that vitrified and metal bonds will outlast resinoid bonds by at least three-fold.

"In retrospect, 10 years ago the life of resinoid bonded wheels was approximately one-seventh that of a resinoid wheel made by today's improved techniques.

"Therefore, it follows that a given amount of diamond powder when bonded in today's vitrified and metal bonded wheels will do approximately 21 times the amount of work that it did 10 years ago. Supply of diamond was ample at that time and during Korea supply would have been more than sufficient if scare buying had not occurred.

"We know the diamond industry has had many problems and solved them in the past and will continue to have and solve future problems under both normal and emergency conditions.

"Let us do everything possible to make our country self-sufficient, but let us also remember that the diamond industry, like all American industry, is capable of living up to what is expected of it."

And from another specialist of still another important producer of diamond tools and products, we quote the following opinions concerning substitution in the processing of sintered carbide tools:

"It is equally possible to grind sintered carbide with silicon carbide wheels but nevertheless our important carbide fabricators, including the basic manufacturers, use diamond wheels and in fact resinoid diamond wheels in many cases because they not only cut faster and cooler but actually present economics in labor and in costs. * * *"

Applications No. 2—Sawing and lapping of metals, gem material, jewel bearings, building stones, concrete, ceramics, glass (including optical), and the drilling and

polishing of diamond and carbide wire drawing dies and other dies, etc.—Most of the 20 percent of crushing boart (the lowest grade of diamond) that remains after providing for carbid processing, is utilized under the heading of these applications.

It is used with oils or liquids, in paste, or bonded into discs. This would account for the consumption of 12 percent more or less of all industrial diamonds.

Substitutes can be used in several of these processes, but at considerably higher cost in labor and equipment. In many cases, fine finishes and tolerances could be obtained only with difficulty. We quote from a technical authority:

"In as simple a matter as glass grinding our top optical companies have found that a metal bond diamond wheel will remove so much glass so fast that they simply cannot afford to use silicon carbide wheels at a fraction of the price of diamond wheels. Diamonds are more costly per unit of weight as compared with any other material that can be purchased to do the job and, therefore, on the surface, they would appear to be a material easy to displace."

Applications No. 3—Diamond tools are dressing and trueing abrasive wheels and shaping same.—The diamond in grades higher than crushing boart (which is the cheapest grade) total from 20 to 35 percent of all importations. Of this percentage about half is used for this purpose, extremely important in the production lines. And thus this accounts for about 12 percent of total industrial diamond importations.

Substitutions with other materials and methods is entirely impractical except for such an infinitesimal percentage as not to merit computation. We quote from a competent technical authority as follows:

"As far as wheel dressing is concerned, there are many types of wheel dressers other than diamonds, such as mechanical dressers, etc. Nevertheless, where fine finishes are wanted on work or where an accurate form must be put into a wheel, diamond dressing is a 'must.' It is perfectly possible to crush a shape into a wheel with a crushing roll, but in almost every instance a diamond dresser is used to finish up the wheel to accurate dimensions."

American industry is continually increasing the use of precision grinding machines for fabricating metal parts. In order to obtain the fine finish and accuracy required, it is necessary to dress the grinding wheels with diamond tools.

Mechanical dressers of one type or another have been used, but only on rough work, particularly snagging operations. There has never been a critical shortage of diamonds used for wheel dressing.

Application No. 4—Diamond drilling for exploration, for mining and oil production.—Nearly half of the better-grade industrial diamonds referred to under application No. 3 are utilized for these most important purposes requiring about 10 percent of total diamond importations. No suitable substitutes have been found that will replace diamond where it so far has been necessary to use it, excepting for minor exceptions. The United States Bureau of Mines has spent great sums and much time in experimenting without significant change in this matter.

Application No. 5—Drawing of wire with diamond dies.—Only a small percentage of total imports is consumed in producing these dies, but the quality of the diamond material approaches that of the gem.

There is no substitute for diamond in drawing the filaments for electric lamps and for the fine wires for the enormous number of parts used in electronic and electric devices.

Carbide dies mainly are in use for drawing coarser wires, and while these cannot be used for the very fine wire, in an emergency the limits can be somewhat lowered at a reasonably higher cost of production.

However, the quantity of diamond consumed in producing the fine small wires is relatively small. The availability of low-grade gem diamonds, should the emergency be great enough, would provide an extra cushion. Besides the above, to the knowledge of the writer of this report, who was officially associated with the World War II problems in this field, there is a large quantity of finished diamond dies and of fine-quality diamond die stones already in stockpile. For the purpose of maintaining American skills for an emergency, there is under consideration by us the making of recommendation to the Government for the increase of the stockpile with American-made fine small diamond dies, but under certain conditions.

While there is no substitute for the fine small dies, in addition to the assurance of sufficient diamonds to make them in an emergency, there was developed, under the administration and supervision of the writer of this report, a substitute electro-method for the production of small diamond dies.

The electro-method is successful for the most critical stages of small diamond-die production. Because of it, in the industry leaders' opinions, there could not be any shortage of diamond dies, even in a war lasting a decade, providing sufficient encouragement is given by Government to enable diemakers to retain their highly skilled specialists, which they find it very difficult to do in peacetime, and also the following: That there be an extension of the electro-methods into the other stages of small diamond-die production. A recommendation to the Government is under consideration by us for research assistance therein. But it is not believed this would be practical unless the research were performed in industry and under certain conditions.

Applications No. 6—Sundry smaller consumers of industrial diamonds.—Percentagewise, possibly the remaining 1 or 2 percent of all industrial diamonds imported are used as tools for boring and turning nonferrous metals and plastics, etc., lens drilling, glass cutting, etc.

Summary and conclusions.—Our carefully considered opinions, based on the above facts, which in turn are founded on the experience of specialists in the industrial diamond field, would resolve to the following:

(*a*) Approximately 35 percent of all industrial diamonds (including crushing boart as the major type) could be substituted for in times of war emergency, with the qualifications that follow.

(*b*) While the cost of substitution might be somewhat high, it would not be too high in terms of defense costs in an emergency.

(*c*) There would be required somewhat more mechanical implementation and manpower in some of the other processes, to effect this substitution.

(*d*) Due to the qualities of the diamond which is over 300 percent harder than any other natural or synthetic material, even a further development of substitutes would not, in our opinion, make them more than substitutes and as such, subject to the above disadvantages.

(*e*) Nearly all of the substitutes discussed are confined to the grinding of sintered carbide tools which consumes a majority of all industrial diamonds used.

(*f*) A careful consideration of the above addendum, together with the statement which precedes it, leads us to emphasize the main facts presented in the statement. These are, that industry together with wartime controls as established during Korea and in an extremity with the Government stockpile as a reserve, can handle all problems of supply, distribution, and orderly development. This includes any necessary conservation and the substitutes. Attention is invited to the one diamond product which might require an "assist" through stockpiling, and this is covered under "Applications No. 5," Diamond Dies.

(*g*) In consideration of the above, no true shortage of industrial diamonds would occur, even in a war lasting very many years, and no "false shortage" would long remain.

(*h*) There is no requirement for Government financed or sponsored research for diamond substitutes. The only qualification of this statement concerns the electroproduction of diamond wire drawing dies, as indicated in the last sentence of "Applications No. 5," but this does not involve a substitute for the diamonds, merely for part of the die-making process. Please see attached supplement, dated January 20, 1955.

The names of the many authorities referred to are available should the committee desire to know them.

A. D. L.

SUPPLEMENT TO STATEMENT OF NOVEMBER 17 AND ITS ADDENDUM OF DECEMBER 8, 1954

(Supplement to: Applications No. 5, Wire Drawing Dies, p. 7 (addendum, p. 4))

The addendum above referred to, at the suggestion of Senator Malone, was prepared and submitted to your committee subsequent to the hearing of November 17. Herewith I submit to the committee the opinions of members of one segment of the industrial diamond industry as some special notice appears to be required. The segment consists of diamond wire drawing die producers, of whom it is believed there are within this association, if not the majority in numbers of small diamond die manufacturers, at least the producers of a large majority of such dies made in the United States.

Chairman Malone, at the hearings and at other times, cited the committee's intention to assure the self-sufficiency of this country, in strategic materials and products, with the accent on those items for which this country depends upon

other lands which might not be able to supply us should a war occur. In my statement made to the subcommittee on behalf of members of this association, and in its addendum, it was demonstrated, and we trust well, how the industrial diamond industry is believed to be prepared for self-sufficiency at all times without Government support excepting the maintenance of an industrial diamond stockpile: That American industry and the industrial diamond group has proven itself capable of using and stretching the supply so as to make the country self-sufficient, providing so-called diamond substitutes were used to replace a substantial percentage of the diamond requirements, albeit somewhat uneconomically.

It was also shown that small diamond dies (meaning 0.0015 inch and smaller) of utmost strategic value in the production of all of the lamp filaments for all electric lights and for the fine strategic wires that are in the multitude of parts for the electronic and electric fields, have no substitutes. It was indicated that for this one exception, Government assistance might be required in research and possibly through stockpiling of the finished product—the fine, small diamond dies.

The main difficulty for the maintenance in America of production of these fine, small diamond dies, lies in continuous retention in the producing plants of certain skilled artisans. These have a special aptitude for work of an extremely tedious and precise nature. The industry loses such men, who would rather do almost any other precise work than small diamond diemaking. The diemakers often are unable to pay the high wages, and only the rewards of higher wages might cause these men to continue in their work. The lack of Government statistics (see Rec'd'n "C," p. 2 following) prevents knowing the amount of die importations in the small strategic sizes. Some members believe that the situation has encouraged importations to the extent that the majority of the small diamond dies used in this country come from abroad, but some of the importers do not believe so.

The importers of diamond dies with whom stockpiling has been discussed would themselves prefer to manufacture the small, fine dies in this country if the economies of the operation permitted them to do so and the skills remained available. However, under existing conditions, the lower labor markets of Europe and the different work attitudes of the European artisans, make it possible to produce the fine, small diamond dies overseas at prices with which this country cannot compete at a profit, if the quality is as good. If it were possible to allot sufficient space in this supplementary statement and recommendations to describe the processes of small diamond diemaking, almost microscopic dimensions being involved, your committee would be able to draw these conclusions for themselves.

Self-sufficiency in the production of strategic products is the stated aim of the subcommittee, but this would not be obtained for fine wire-drawing unless the skills for the making of the critical diamond dies were maintained in the face of existing difficulties. In addition, American plants would need to effect an almost complete production of the small diamond die by the modern electromethods. To bring this about would require research financed by Government.

After very many years' observation, it is our considered opinion (1) that if the electroprocesses are not completed, the cost of fine small diamond die production of equal quality in this country cannot be brought low enough to compete with the foreign product, and that it would not be possible to conclude the necessary research and experimentation in less than a period of years. (2) The rare skills of small diamond diemakers (though less artisans would be needed) still would be required later in the complete production of the diamond dies by the electromethods, and in the finishing processes not believed possible except by hand. It would become necessary, in the interim, in order to encourage the manufacturers of fine small diamond dies to maintain the rare skills in their plants, to have Government orders placed with them for their product.

The following therefore is recommended to the Senate's Minerals, Materials and Fuel Economic Subcommittee:

(*a*) That Government finance research by highly skilled electromechanics to perfect those stages of fine small die production that still are possible only by entirely mechanical means; that this be done in the two main diamond diemaking districts: Fort Wayne, Ind., and the New York-New Jersey areas; further, that this research be under the direction of those diemakers of the two regions who now are experienced in the electroprocessing of the most critical parts of the die. Successful conclusion of the project would depend upon such supervision.

(*b*) That Government place orders amongst the producers of fine small diamond dies for the Government stockpile according to a reasonable pattern of

allocation; that the orders provide for delivery over a period of years, and at a price that will permit the producers to pay what is required for the maintenance of highly skilled American artisans in the production of fine small diamond dies.

The majority of the diemakers in this association state that if there is to be stockpiling of Government small diamond dies for the encouragement of skills, as outlined above, the maintenance and training of the necessary artisans could not be accomplished unless such dies were American made. The minority, who produce dies in the United States but also import small diamond dies, feel that the stockpiling should consist of imported dies as well as American made, so as to insure the necessary supply of fine quality small diamond dies against all eventualities.

(c) That Government require the Census Bureau to break down its statistical reports on the importations of diamond dies in such a way as to make it possible to determine the quantity imported of diamond dies in the small sizes. These are the only ones which it is believed could become critical in war time. Required breakdown is as follows:

Sizes 0.0015 inch and smaller ———. Number of dies ———. Carat weight ———. Value $———

Sizes 0.0016 inch and larger ———. Number of dies ———. Carat weight ———. Value ———

The statistics have but one ancient heading. "Manufactured Bort." These show the total weight in carats and value of the imports combining the common or larger sizes, the small diamond dies with which we are concerned and a few minor items. If plans are to be made for the self-sufficiency of the United States in small dies, it is imperative that Government and Industry shall know to what extent we are dependent upon imports from Europe.

A. D. L.

Senator MALONE. We also have with us today Mr. R. B. Saltonstall, technical director of the Udylite Corp., Detroit, Mich.

Do you have a statement prepared?

STATEMENT OF R. B. SALTONSTALL, TECHNICAL DIRECTOR, THE UDYLITE CORP., DETROIT, MICH.

Mr. SALTONSTALL. I do, sir.

Senator MALONE. You may proceed. Identify yourself first for the committee and then go ahead in your own way.

Mr. SALTONSTALL. I am Dr. R. B. Saltonstall, technical director, Udylite Corp., Detroit, Mich.

Gentlemen, I have been asked to describe research and development work in connection with alternates, replacements, and substitutes for, as well as synthesis of, critical materials used in the electroplating industry.

ALTERNATES, REPLACEMENTS, AND SUBSTITUTES FOR CRITICAL MATERIALS USED IN ELECTROPLATING

The description will be brief for the simple reason that in spite of a very considerable amount of work in a number of laboratories, and extensive attempts to translate the results of this work into pilot plant and production operations, the final results have been far from satisfactory.

Our principal problem in times of national emergency is the availability of such critical metals as nickel. cadmium, tin, copper, and to a lesser extent, zinc. Lead, too, is usually in short supply, but is used in plating in much smaller quantities than the other metals mentioned. When these metals are in short supply, their chemical salts with which plating solutions are prepared and maintained are equally difficult to obtain.

Nickel, which is very high on the list of critical materials, is by far the most serious problem in the electroplating industry. It is a metal which is usually resistant to corrosion, and is applied by electrodeposition in films, varying in thickness from a few tenths of a mil to 2 mils on iron, steel, zinc, copper, and brass to protect and beautify a wide variety of articles. The term "chrome plate" used so commonly is a misleading one. In most cases an extremely thin chromium deposit (0.01 mil) is applied over a more substantial coating of nickel for the prevention of tarnishing and scratching. Such chromium deposits are valueless for protection against corrosion when applied directly on a steel or nonferrous basis metal.

Senator MALONE. Tell us, unless you go into it further, how is this applied to the surface?

Mr. SALTONSTALL. The technical details?

Senator MALONE. Yes.

Mr. SALTONSTALL. The article to be electroplated, if it is large, is hung or clamped on a fixture which will conduct electrical current to the article. The fixture bearing the article is then immersed in a tank which contains an electroplating solution. Direct current is applied. The article to be plated is made cathodic by connecting it to the negative side of the direct current source, and in most cases anodes of the metal to be deposited are connected to the positive side of the direct current source.

The current is turned on and the quantity of current which flows per unit of surface area of the work, the time, and the cathode efficiency of the process determine the thickness of the coating which is applied. A variation of this procedure is to handle work such as small screw machine parts, nuts and bolts, in bulk, in cylinders made of nonconducting materials which are continually rotating in the plating solution, the mass being made cathodic by electrical contacts within the cylinder. The exterior of the cylinder is perforated so that the current may flow through the perforations in the cylinder without the small bulk of the work dropping out of the cylinder.

Does that answer your question, sir?

Senator MALONE. Yes; it does.

Are any of these materials applied in any other way except electroplating, in a plating process?

NICKEL PLATING

Mr. SALTONSTALL. Yes, sir; they are. Nickel is applied to steel in a cladding operation. Perhaps you are familiar with it.

The ingot of steel is milled or machined to rather accurate dimensions and flat surfaces and then a rather thick sheet of nickel is laid on it. Both are heated and the two rolled together, so that the nickel at the interface between it and the ingot is bonded to the steel and at the same time the thickness of the total is reduced, much as steel is rolled, especially hot rolled steel.

There is a process recently being promoted and used to a limited extent for depositing nickel on steel without the use of electrical current. Chemical reduction is used. The process is very costly but is applicable to intricate shapes which are not easily adaptable to electroplating. As far as I know, those are the two principal methods, other than electroplating.

Senator MALONE. Do shapes immersed in this mixture affect the way or the manner in which deposits are brought about?

Mr. SALTONSTALL. Very definitely, sir. The distribution of direct current over the surface of the article determines to a large extent the distribution of electroplated metal.

Senator MALONE. And the time and the mixture itself determines the thickness and so on?

Mr. SALTONSTALL. It determines the average thickness. On a very complex shape the areas which are deeply recessed, more inaccessible to flow of current through the electrolyte, are covered with appreciably thinner deposits than protruding surfaces.

Senator MALONE. In other words, it is a matter of effectiveness of the current?

Mr. SALTONSTALL. That is correct, sir.

Senator MALONE. I think that is all. The committee might have a curiosity as to just how it is done.

RESTRICTIONS ON USE OF NICKEL

Mr. SALTONSTALL. Nickel plate depends, to a great extent, on its thickness for its protective value, and the poor quality of much of the automotive hardware manufactured during and since the Korean emergency is directly related to limited supply of nickel, together with specific prohibitions regarding its use. During this emergency, the quantity of nickel available monthly through conventional channels for electroplating civilian goods varied between 10 and 30 percent of the 1949–50 period on which allocations were based. Even now with restrictions on end use removed, the allocations are only 35 to 50 percent of the same base period, the average being about 40 percent.

UNSATISFACTORY SUBSTITUTES FOR NICKEL-CHROMIUM PLATING

A number of substitutes for nickel-chromium plate were used during the Korean emergency. One of these was a copper plate 1 to 2 mils in thickness, to which was subsequently applied 0.01 mils of chromium plate. This combination was worthless for outdoor use unless further protected by a clear synthetic lacquer or enamel, and the final permanence of the combination was entirely dependent on the synthetic coating. This combination was more costly to apply than a copper-nickel-chromium or nickel-chromium deposit, and much less resistant to corrosion and abrasion.

Another combination which was substituted rather widely in finishing items on which the use of nickel was prohibited was a white brass-chromium combination. The white brass was an 85 percent zinc, 15 percent copper alloy. It could be plated bright, but the deposit was very brittle, and tended to stress-crack when chromium plated if more than 0.3 mil thick. When exposed to the weather, unsightly white corrosion products of zinc soon bled through the chromium deposit. Attempts to bake a clear synthetic on this combination resulted in further unsightly stress-cracking. In addition to the poor result, the plating process itself was difficult to handle and caused serious operational difficulties.

Bright zinc with a subsequent chromium deposit was tried early in the emergency, but so far it is not possible to deposit chromium bright direct on zinc.

Several attempts were made to develop a process for plating antimony as a nickel substitute but the extreme inherent brittleness of this metal could not be overcome. It is also doubtful if health authorities would have permitted its use because of the highly toxic nature of some compounds of antimony which might be liberated in the processing operations.

Attempts were made during World War II to produce cars with painted bumpers, guards, grills, and other hardware which is normally nickel-chromium plated. The tremendous losses in resale value of these cars precluded similar attempts during the present nickel shortage.

Work is still going on to a limited extent in a search for a satisfactory alternate for nickel-chromium plate, but the probability of success seems rather slight.

Cadmium and zinc are electroplated on steel and nonferrous metals principally for protection against corrosion. They have the unusual property of protecting these basis metals by electrochemical action rather than dependence on a completely continuous envelope. For this reason the thickness of film is usually low, on the order of 0.1 to 0.5 mil. They can be plated bright, and when protected further by clear lacquers will retain their pleasing appearance for a considerable time if the exposure is mild.

Cadmium, although considerably higher in price, has a number of important advantages over zinc. Solderability, resistance to weak acids and alkalis, electrical conductivity, and superior resistance to tarnish are a few of these. However, zinc can be satisfactorily substituted for cadmium in a wide variety of electroplating applications, and this is being done, to such an extent that cadmium is currently in excess supply. However, future shortage of cadmium is predicted by the Bureau of Mines. The use of chemical surface treatments on plated zinc makes possible its substitution for cadmium in many applications.

The principal use of tin in electroplating is on thin steel strip subsequently formed into tin cans for food packaging. The savings in tin consumption effected by changing from the old hot-dip methods to electrodeposition during World War II are well known.

While rubber may no longer be considered a critical material, it has been during past emergencies, and the electroplating industry has utilized synthetic plastic linings for tanks which are for many uses superior to rubber.

Corrosion resistant alloys containing high percentages of nickel have been used in contact with acid solutions and vapors. In many instances these alloys have been replaced by mild steel completely enveloped in heavy plastisol type films.

In conclusion, the electroplating industry, which normally employs well in excess of 100,000 people, and produces protective, decorative, and functional coatings having an estimated value of more than $350 million annually, has suffered worse than many industries using critical metals and materials. Attempts to develop satisfactory alternates for the metals used have met with little success. It should be emphasized that because of the thin coatings applied, in no other industry can so little material, spread over so large a surface area, achieve such savings of labor and dollars and the protection and preservation of such a vast variety of manufactured articles.

Senator MALONE. If you have made any estimate, what is the tonnage of each of these metals that you have mentioned that is normally consumed in this business of electroplating?

Mr. SALTONSTALL. I have some figures here, Bureau of Mines figures, by year, especially with respect to nickel. In 1949, 14,500-odd short tons; 1950, 19,000.

Senator MALONE. That is pure nickel?

Mr. SALTONSTALL. Pure nickel, yes, sir.

Senator MALONE. Fourteen thousand tons in what year?

Mr. SALTONSTALL. 1949. 1950 was 19,000; 1951, 6,000; and 1952, 7,000. 1951 and 1952, of course, were the allocation years.

Senator MALONE. What did they use then?

Mr. SALTONSTALL. Six thousand and seven thousand short tons, respectively.

Senator MALONE. Do you have the tonnage on any other material there?

Mr. SALTONSTALL. I have a figure on cadmium.

Senator MALONE. I think that is rather important.

Mr. SALTONSTALL. In fact, I think I got the figure from the report. Nine million nine hundred thousand pounds was the consumption, and we estimate that about 75 percent of that was used in electroplating. Electroplating is by far the largest single use for cadmium at the present time. I do not have figures at the moment for other metals.

Senator MALONE. Could you secure any estimates?

Mr. SALTONSTALL. I can try. I am not sure they are available.

Senator MALONE. I wish you would try. You see, for us to give any thought to the importance of the industry, we would have to know the approximate tonnage or the number of pounds involved over a period of years. Please do the best you can.

I suppose that this business of electroplating—that is, the method of electroplating; the use of these materials in electroplating in place of paint—would save quite a good deal of wear and tear on the metals protected. Not only is it decorative in many cases, but it also saves the material; does it not?

Mr. SALTONSTALL. Very definitely. I would like to emphasize the protective value of electroplate coatings.

Senator MALONE. Would you do that?

Mr. SALTONSTALL. It is extremely difficult to separate the decorative and protective values of any electro deposited coatings.

Senator MALONE. Of course, in wartime we would be interested only in the protective value.

Mr. SALTONSTALL. That is true. And I am perfectly sure that under presence circumstances, in the event of war, there will be no nickel-plating. You can be perfectly sure of that.

Senator MALONE. In other words, you would substitute paints or some other protection?

Mr. SALTONSTALL. I would like to see the industry get what we consider a more equitable share of the metal available for civilian use at the present time, but I do not think that is within the jurisdiction of your committee.

NICKEL ALLOCATIONS

Senator MALONE. What metal is it now that is being rationed?

Mr. SALTONSTALL. Nickel is allocated to our industry.

Senator MALONE. At this time?

Mr. SALTONSTALL. At this time. By the International Nickel Co.

Senator MALONE. There is nothing being rationed by the Government; is there?

Mr. SALTONSTALL. To the best of my knowledge, the Government tells INCO to first take care of the military needs and stockpiling requirements, then distribute the balance available to civilian industry on an equitable basis.

Senator MALONE. By INCO you mean the International Nickel Co.?

Mr. SALTONSTALL. Yes.

Senator MALONE. They take care of the needs and allocate it themselves?

Mr. SALTONSTALL. They allocate for civilian use; yes, sir.

Senator MALONE. Could you give us more information on that basis? That is, you do have the allocations; you have what is allocated to national defense and what is allocated to civilian uses. And then the amounts allocated to civilian uses, you have that, do you not? Is that available to you?

Mr. SALTONSTALL. That is not available to us; no, sir.

Senator MALONE. It is a trade secret; is that it?

Mr. SALTONSTALL. I am not sure why it is not available.

Senator MALONE. Well, you see, if it is a Government allocation it would be available to you, if it was not in wartime. It probably would be even in wartime.

Mr. SALTONSTALL. It is available through the Bureau of Mines figures, I think.

Senator MALONE. Do you mean in wartime, or is it available now?

Mr. SALTONSTALL. I think it is available now through the Bureau of Mines.

Senator MALONE. Why do you not get it for us? If you have any difficulty, let us know about it and perhaps we can finish the job for you.

Mr. SALTONSTALL. Let me check that here.

Senator MALONE. It seems a little silly to me, as chairman of the committee, that we are rationing anything in peacetime unless there is a real necessity for a fast construction job on some particular job where a certain metal is required suddenly.

Mr. SALTONSTALL. The way that is explained to us, sir, is that the current production of nickel is not sufficient to satisfy: (1) stockpiling requirements; (2) military requirements; and (3) civilian requirements.

Senator MALONE. Why?

Mr. SALTONSTALL. Why is it not great enough? I assume it is because production capacity has not yet been built up to the required amount.

Senator MALONE. Is that it, or is it just a question that the production is controlled by a very few companies and maybe they do better by rationing?

Mr. SALTONSTALL. I doubt, sir, if the latter is the case.

Senator MALONE. What is the production now as compared to the war production periods?

Mr. SALTONSTALL. It is greater. I do not know how much. I do not have those—well, here. Yes, I do. Consumption figures, Bureau of Mines, total consumption—this does not include stockpiling—

187 million pounds in 1948; 1949, 136 million pounds; and 1950, 197 million pounds.

In 1951, down again, 172 million; 1952, 202 million; and 1953, 209 million pounds.

Senator MALONE. What was 1953?

Mr. SALTONSTALL. 1953 was 209,562,000. It has been increasing, with the exception of 1 year, since 1949. I think those figures are a matter of your record.

Senator MALONE. Now, are you aware that perhaps in the Western Hemisphere there is probably more nickel than we would know what to do with if properly developed, like in Cuba and elsewhere?

Mr. SALTONSTALL. Yes, sir; I am.

Senator MALONE. There is a movement on now, and the Government is putting some money into it, although how much I do not know, but we will have a witness who will know about it, with advancement of money and money being expended in laboratory work by certain companies of themselves. But there is every possibility that within a relatively short time, in the estimate of engineers familiar with it, that there is very little excuse for a shortage in nickel. We had a setup when we came in here 2 years ago where they would fix the price in peacetime below what would encourage real production, and then ration the use in wartime. It kept the rationeers busy the year around, and between wars and through wars and everything, but to some of us it is just an unusual procedure that the Government should not be in.

Would you have any ideas on the subject?

Mr. SALTONSTALL. I have been through two national emergencies in my present connection—the first one was World War II. There apparently was not enough nickel being produced at that time to satisfy military requirements, and nickel-plating on civilian goods was stopped completely. During the recent Korean emergency it was the expressed purpose to maintain a dual economy. The civilian economy suffered very badly with respect to nickel, again because there was not enough being produced to satisfy stockpile, military, and civilian requirements.

Senator MALONE. There is some suspicion that industrial diamonds are handled like that.

Mr. SALTONSTALL. I am sorry; I know very little or nothing about industrial diamonds.

Senator MALONE. And regular diamonds, that the production is rationed. That would have nothing to do with our friend who just testified here. He is on the receiving end and probably suffers as much as anybody else.

Mr. SALTONSTALL. So are we.

Senator MALONE. The committee is very much interested in anything that the Government rations or that private industry rations or in any way controls in peacetime and then they are short in wartime. We want to go to the bottom of it if we can.

Mr. SALTONSTALL. I noticed from reading your record of previous hearings that there was practically nothing said about any severe shortages of nickel in the civilian area at that time.

Mr. ADLERMAN. I think if I recall correctly, we did have a hearing on nickel: and if my recollection is correct, it is that the nickel allo-

cations had been taken off and some of the Governmental agencies—I believe it was Office of Defense Mobilization or the Department of Commerce—had made some arrangement with the International Nickel Co. to allocate it on its own basis, in a fair manner, and industry was highly unsatisfied with it. That took place, I think, about a year and a half ago.

Senator MALONE. Yes.

You pay for the nickel whatever they charge for it. That is the only source. International Nickel Co. is the only source, or maybe there are a couple more. But they can easily get together or perhaps have enough of the production so they did not even need to talk to another producer and fix the price, and no one bothers about arguing about the price if he is being reduced in his allocation. That would hurt him.

What is your thought along that line? Have you ever thought it through to see what the effect is?

Mr. SALTONSTALL. No, I can't say that I have. There are a number of firms in the electroplating industry who are distributors of nickel anodes for the International Nickel Co. We all cover the same area. There are no geographical restrictions for the distributors, so we must be competitive. The price, barring small inconsequential exceptions, is uniform throughout the industry, differing only because of freight rates. We have been led to believe that there are large developments in nickel mining and production in the making which should, within a few years, relieve our situation appreciably.

Senator MALONE. Are they by independent companies?

Mr. SALTONSTALL. You mentioned one, the Cuban development. I believe Sheritt Gordon in the Lynn Lake area in Canada is another big one that is coming along. I do not know of any other major activities outside of those two.

Senator MALONE. Have you ever given it any thought as to what the situation is in regards to these various metals that you need and do use in your business, or is the price inconsequential with you, or the rationing?

Mr. SALTONSTALL. Rationing is not inconsequential by any means, but we feel rather powerless to do anything about it.

Senator MALONE. If there were production enough so that rationing would not be necessary and were not allowed, were not permitted, would it be helpful?

Mr. SALTONSTALL. In the case of nickel, it most certainly would.

Senator MALONE. Would it in any metal or any product?

Mr. SALTONTALL. Nickel is our only serious problem now. In times of emergency we also get in trouble with cadmium as well as tin, which is from outside of the country, to a large extent.

Senator MALONE. Did you know our report covered the tin situation? You know what happens there. There is enough tin in the Americas, in the Western Hemisphere, to supply the smelter in Texas, and the smelter has capacity enough to run us in wartime—40,000 tons. We are consuming now about 60,000 tons annually. But it is a commodity that in wartime you consume less than you do in peacetime, for various reasons.

There are certain industries that use it in peacetime that would not be operating too much in wartime, according to the testimony. Bo-

livian ore is shipped to England to be refined, and most of it comes back here and is sold to us. It crosses the ocean twice. We get a large supply of our tin for the Texas smelter from the Malayan states and Indonesia.

The State Department recommended that we do away with the Texas smelter and depend entirely on offshore refineries, across oceans. It did not make much sense to this committee, and I do not believe the Government will do that.

The committee's target, if it has any depends on bringing these things to the attention of the people and the Congress.

What do you think about that?

Mr. SALTONSTALL. I very much ascribe to the activities and objectives of the committee and the methods with which you are proceeding to do these things.

Senator MALONE. I appreciate your saying that very much. The reason I am questioning you beyond your statement is to find out if you have any ideas that will be helpful to the committee. If you do, when you get your testimony back for correction and completeness, give it to us.

Mr. SALTONSTALL. Very good, sir.

Senator MALONE. You see, this committee can only be as efficient as the information it can receive.

Tell us what effect rationing has on you in peacetime and wartime, both by the Government and any private industry. We appreciate your coming here and the time you have taken away from your business. We are sorry we could not hear you this morning.

Mr. SALTONSTALL. It has been a pleasure to be here, sir.

Senator MALONE. The committee will stand in recess until 9 o'clock tomorrow morning.

(The following material was subsequently furnished for the record:)

ADDITIONAL FIGURES AND COMMENTS IN CONNECTION WITH TESTIMONY OF DR. R. B. SALTONSTALL, OF THE UDYLITE CORP.

You asked that I obtain figures on the quantities of various metals plated annually. The following figures are, in my opinion, as accurate as can be obtained.

	Pounds per year
Lead	1,000,000
Silver	1,000,000
Copper	16,000,000
Zinc	30,000,000
Chromium	4,000,000
Tin	50,000,000

You asked for a breakdown of the quantities of nickel currently being allocated to national defense and civilian uses, respectively. I have been unable to obtain such figures but, as appears in my testimony, civilian electroplating is able to obtain currently through regular channels only 35 to 40 percent of the quantity used in 1949 and 1950. The quantity allocated to our industry was decreased slightly in November and further decreased in December.

You asked me to dwell further on the effect of rationing, both by Government and private industry, in peacetime and wartime.

Rationing is almost always the direct result of short supplies, either temporary and artificial, or real over a long period of time. In periods of national emergency, rationing is undoubtedly necessary in order that military demands are met and available balances of materials are distributed equitably to civilian industry. Even at the present time, the rationing of nickel, as stated earlier in my testimony, is necessitated by the fact that the supply is insufficient to meet the requirements of the stockpile, national defense, and civilian industry.

Shortages of metals in the electroplating industry create various combinations of the following undesirable situations: (1) A black or gray market with attendant inflated prices; (2) curtailment of production of electroplated goods; (3) production of electroplated coatings which are too thin and correspondingly of poor quality; (4) economic hardship and dislocation of labor and facilities into other industries.

An electroplated coating of nickel, zinc, cadmium, or other metal may look very attractive to the eye and still be far too thin to furnish the protection required for the intended service. Many years ago, electroplated coatings were thought of as largely decorative because the metals were not applied in films of sufficient thickness to afford a reasonable degree of protection to the underlying metals which uncoated will quickly rust or corrode in service. Education, experience, and technological advances have, to a large extent, overcome this prejudice, but every time insufficient supplies of metal occur, some of these hard-earned gains are lost by the industry.

(Whereupon, at 5:03 p. m., a recess was taken until 10 a. m., Thursday, November 18, 1954.)

STOCKPILE AND ACCESSIBILITY OF STRATEGIC AND CRITICAL MATERIALS TO THE UNITED STATES IN TIME OF WAR

THURSDAY, NOVEMBER 18, 1954

UNITED STATES SENATE, SUBCOMMITTEE ON
MINERALS, MATERIALS AND FUELS ECONOMICS OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D. C.

The subcommittee met, pursuant to recess, at 10:35 a. m. in room 224 Senate Office Building, Senator George W. Malone presiding.

Present: Senator Malone.

Present also: Jerome S. Adlerman, chief counsel; George B. Holderer, staff engineer; N. D. McSherry, chief clerk.

Senator MALONE. The subcommittee will be in order.

I want to say I owe an apology to the witnesses who have traveled some distance here. Probably you do know that we have several things on the fire. We do intend, regardless of what happens when the Senate finishes its work on the current controversy, to go to South America.

The chairman has personally visited all the nations of Central America, Mexico, Panama, and Colombia, but has not been south of Colombia. He has visited many nations and, as chairman of the committee, conducted the work that resulted in a basic report.

Contrary to things that have been told to this Nation for a good many years, the chairman does not believe there are definite answers to all economic problems. If there were, we would all be rich.

So we have only started with that basic report.

You are familiar with the fact, without any doubt, that under Senate Resolution 143, directing this committee to make an investigation and report to the Senate on the accessibility of the critical materials in time of war, for expanding economy and for our security, was the framework under which we made this basic report.

It was submitted to the Senate in July. It has become Senate Report 1627, a copy of which you have no doubt seen.

STATEMENT OF FRANCIS C. FRARY, TECHNICAL ADVISER, ALUMINUM RESEARCH LABORATORIES, ALUMINUM CO. OF AMERICA

Mr. FRARY. Yes.

Senator MALONE. Now, the Senate extended the work of the committee through Senate Resolution 271, which has already been made a part of the hearing. But it simply expanded the work specifically. I do not think we needed it except to be clear on what was implied in the other resolution. But this one specifically says that this com-

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mittee is directed to investigate and study the best means and methods to foster the greatest measure of self-sufficiency of critical materials, which includes substitution, replacements, and such. It goes on in some detail.

So we called you, Doctor, because of your personal reputation and the fact that you do represent a very stable and powerful company—powerful in the nature that it has become a definite part of the economy of the United States of America.

So if you will identify yourself for the purpose of the record, if you have a written statement you can read it, or you can proceed in any way you see fit to present the data.

Mr. FRARY. I am Francis C. Frary, technical adviser of the Aluminum Company of America. I was director of research for this company from December 1918 until I retired on the 1st of January 1952, and I am testifying at the request of the committee.

Senator MALONE. You are sort of an adviser emeritus now, are you not?

Mr. FRARY. A director of research emeritus; adviser, rather actively, a good deal of the time.

The industry, as you know, is relatively new. It has been only about 65 years since the present aluminum industry began, and aluminum became commercially usable. Our company was a pioneer in this country in the development of the process, and until substantially the beginning of World War II we were the only people here who did produce aluminum.

Senator MALONE. I recall when we were discussing transmission lines out in Nevada. In 1927 and 1928 in Nevada it was even problematic then whether the aluminum would do the work, certain work in place of copper. It had never been tried out, even at that time, on a large scale. And in certain fields at least it has replaced copper.

PROGRESS OF ALUMINUM

Could you tell us how long ago it was and how long it took from the time alumium was well known in texture and the experts knew what it would do, or thought they did, before the price came down to the point where it became competitive and manufactured on a large scale? What was that time element?

Mr. FRARY. The time element there was quite a good many years. The first commercial production of aluminum was in France, way back in the time of Napoleon III, who encouraged it because he thought he could make light armor for his army.

But until Mr. Hall in this country, and Heroult, in France, discovered about the same time, in 1886, the present process, the cost of aluminum was up around $8 or so a pound, at least that much.

Senator MALONE. When Louis Napoleon was so attracted to it, it was at a much higher cost than that, was it not?

Mr. FRARY. Yes, it was much higher. It was as expensive as gold, or more so; because it had to be made with a laboratory process.

Shortly after production in this country began, the cost had dropped very decidedly, and by the time of the First World War we were getting about 33 cents a pound for aluminum and it had gone to very wide use.

The aluminum electrical conductors to which you refer were first used by our own company when we went into production in Niagara Falls. We were the first customers of the Niagara Falls Power Co., and I believe that was about 1895. And we used an all-aluminum cable to bring our power from our powerhouse to our plant.

That was found to be unsatisfactory because it was not strong enough for miscellaneous uses, and early in the 1900's, I think about 1905 or 1906, our chief electrical engineer, Mr. Hoopes, invented and developed the aluminum cable with the steel core, which has become standard all over the world for high-tension cables.

Over 2 million miles have been installed in the United States. It has become so successful that the Anaconda Copper Co. and, I believe, one of the other copper companies are now manufacturing it and selling it instead of copper cable for high-tension work.

So the production has gone up and costs have dropped. Our sales price has gone down as low as 15 cents a pound for ingot during the Second World War, and has come up some since then because of continued increases in cost of labor and supplies.

All the time we have been in continuous competition with all sorts of other metals; not only copper, as you mentioned, but brass, stainless steel, tin, lead. We have to compete with wood and paper for some things.

So then the whole situation has been pressing upon us the importance of reducing costs.

One of the things which has enabled the aluminum industry to compete with some of these other industries is that because of a constant and adequate source of the raw material, the price has remained relatively constant during the years when prices of copper and other metals, lead, zinc and so forth, fluctuated widely.

Senator MALONE. In other words, there is a field of replacement, an area in each of these materials that you mentioned, where they are substitutes or replacements?

Mr. FRARY. Yes.

Senator MALONE. It works both ways.

Mr. FRARY. Aluminum has substantially only the market which it has taken from something else. We have had to go out and know more about our material and have additional information about it as compared with other materials so that we could persuade the customer that he would either save so much money or get so much better results with the use of aluminum and he could afford to take the risk of changing his process and equipment so as to use it, taking the chance that maybe his customers might find something they didn't like about it.

All through the years we have had that continual competitive situation, and we have substituted aluminum for copper, brass, zinc, lead, as I said, stainless steel, ordinary steel; other things, continuously to the advantage of the customer and therefore the company.

Senator MALONE. Is not the history of all new materials, too, Doctor, that as the price comes down it expands the field and new fields open up?

Mr. FRARY. That is true.

Senator MALONE. In other words, you can use aluminum in places now where you never could use copper or anything else up until this time.

For example, we are building roads now that were undreamed of, and mining ore undreamed of 25 or 30 years ago because of the large machinery moving large yardages and at a much lower cost. So it just opens up more work.

Mr. FRARY. That is true.

Senator MALONE. That is the history of this metal, is it not?

Mr. FRARY. Yes. We have spent over the years continuously large amounts in research and development, and especially in recent years in engineering development, to help our customers design such things as buses and trains and other moving things; and to be able to prove to their satisfaction that it was worth their while to go to the expense of changing their equipment and substituting aluminum for other things.

Senator MALONE. There is another metal coming along now, called titanium, unknown a few years ago, and costs $15 a pound now. If that price ever came down, would that have a tendency to compete with aluminum or vice versa?

Mr. FRARY. Primarily in one field. Titanium has high strength as compared with aluminum at elevated temperatures, and for the supersonic planes and some parts of guided missiles and rockets and things of that sort, it has a real field largely in competition with stainless steel.

The price will probably come down considerably, but as far as we know now, there is no prospect of its ever getting down to where it would be anything like the cost of aluminum or magnesium.

Senator MALONE. Do you think it would have to remain competitive only in the fields where some particular property, like the heat-resistant property, would make it impossible to use aluminum?

Mr. FRARY. It would make it preferable to use titanium, and where the saving in weight would make it preferable to use titanium instead of stainless steel.

Senator MALONE. The weight is likely to be greater, is it not?

Mr. FRARY. Of course, if you compare pure titanium with aluminum alloys used in aircraft, then it goes in the other direction. But if you compare the high-strength titanium alloys, which are being developed now, with the high-strength aluminum alloys, the titanium alloys have an advantage.

It is particularly true at the elevated temperatures because titanium has a melting point about that of iron; whereas, the aluminum melting point is way below that of copper. It is even, I think, below that of brass. And as the temperature of any metal approaches the melting point, the strength drops off rapidly.

So aluminum and its strong alloys are not ordinarily suitable for work at temperatures very much above normal temperature.

Senator MALONE. You are a scientist, Doctor; you are a research man. You had charge of this field for many years for a very important company.

Is it not true of metal in any field, that the progress made in the laboratory is the final answer; in other words it is not pure aluminum, not pure titanium, not pure iron; it is your alloys you are able to develop with the weight-strength ratio and resistance, and if anyone quit the laboratory for about 5 years, he would be probably out of business. Is that right?

Mr. FRARY. Certainly the alloy development is what put aluminum on the map. Substantially all the alloys used in this country, other than the pure aluminum and one alloy that we use for cooking utensils, have been developed by our laboratories during the time I was director of the laboratories; so you can see the importance of alloy development.

Senator MALONE. Go right ahead with your statement, Doctor.

Mr. FRARY. I was going to point out that the industry has grown very rapidly in the years since the beginning of World War II. In 1939 to 1953 our production in this country increased from 327 million pounds a year to over 2½ billion pounds, and if you include the Canadian industry with their present plans, when they have completed their plans the North American capacity will be about 2½ million tons of aluminum per year; which is something like 10 times the combined production of Canada and the United States at the opening of World War II.

So that, as you see, it is hardly fair to class aluminum as a scarce material when its poundage production is higher than that of copper or any of the other nonferrous metals, although it is still only a fraction of the steel production.

Senator MALONE. One of the purposes of this committee, Doctor, is to determine in the Western Hemisphere, which is ordinarily determined as the area we can defend in time of war, the possibilities of becoming independent, and the committee has already decided from a study of the testimony presented to the committee prior to the report that we can become self-sufficient in that hemisphere.

I suppose you have in your statement before you get through some comparison of the total consumption in the United States of aluminum now, and its alloys, as compared to prior years. Do you?

Mr. FRARY. I just gave you the figures compared with the beginning of World War II. The production will have increased 10 times.

Senator MALONE. The consumption? The United States has increased also?

Mr. FRARY. The consumption has increased. In addition to our own production a considerable amount of aluminum has always been imported. Before the war there was quite a little from Europe as well as Canada. Now a good share of our importation comes from Canada.

Because of the fact that the aluminum industry has to make its market and develop its whole market in competition with everything else, we have had to naturally do everything to keep the cost down, and for all of the life of the industry so far, here and abroad, the cheapest source of aluminum oxide (which is our raw material) has been a high-grade bauxite, or at least bauxite of some grade or other. Until World War II it was high-grade bauxite only.

We prefer bauxite for the same reason that the steel industry prefers high-grade iron ore. You could go out here and take any of this red clay and smelt iron or aluminum out of it, but in neither case could you afford to do it because the cost would be too great.

Senator MALONE. I would like for you, before you get through today, to go into that subject in some detail because bauxite is available in the Americas to a considerable extent, I mean large amounts of it.

Mr. FRARY. Yes.

Senator MALONE. But I also understand that the laboratory experiments, while we have been arguing about it in the last 2 or 3 years have made it more practical to use a lower grade, with a higher silica content, and therefore to that extent extend the reserves.

I have been with this committee for 8 years and of course been aware of its work for many years. This is the committee that furnishes the money for experiments for pilot plants and laboratory experiments, in the Bureau of Mines. And they have experiments going on in aluminum clays. It is my understanding, just roughly, that there is no limit to the hundreds of millions of tons of clays that are running over 10 or 20 or 30 percent aluminum.

It is merely, as you suggest, more expensive to get it now.

Mr. FRARY. That is right.

Senator MALONE. We hope—and I would like to have your opinion on that—if in the foreseeable future the cost might not be substantially reduced in using these clays. If that were the case, it means domestic production would be much more important and would be an easier thing in time of war.

In the last analysis, of course, the economy is terrifically important in this country, economic structure to maintain it, with the higher standard of living; and production.

But when you come right down to the last analysis, our security is more important than anything. And expense in national defense is not the controlling factor. Could we use these aluminum clays regardless of cost, if we had to on account of transportation? I would just like to get into that facet of it if you can.

Mr. FRARY. We have to consider the fact that bauxite of the grade which has always been used, standard bauxite, contains between 55 and 60 percent of aluminum oxide. Most of the clays, so-called clays, which are available anywhere in the world contain from 10 to 20 percent. There are some grades of what are known as diaspore clays and are used for refractory purposes, which contain 30 to 40 percent of aluminum oxide.

You know, of course, that mining costs are an important item, and naturally, if you have to mine 5 times as much material you have 5 times as high a mining cost.

Moreover, the so-called high-grade clays, refractory clays (of Pennsylvania, for instance) are so valuable in the manufacture of refractory materials that we could not afford to use them for the production of alumina.

So we have to consider the fact that in Arkansas we had originally a fairly large supply of what we called specification bauxite, which was about 56 percent alumina and not more than 7 percent silica. We are interested in silica not only because we have to mine and handle more material, as the silica content goes up and the alumina content goes down; but particularly because every pound of silica in the bauxite means that we have to reject and throw away in the mud a pound of alumina and usually something over a pound of soda.

So that the increase in cost of extracting alumina goes up very rapidly.

Senator MALONE. You mean there is a loss?

POSSIBLE SOURCES OF ALUMINUM DURING AN EMERGENCY

Mr. FRARY. There is a loss. It is rejected, this amount of alumina and soda, with the silica.

We have a large quantity of what we might call near-bauxite down there, which we speak of as high-silica bauxite, which ranges all the way from 7 percent up to 25 percent or more of silica, and the alumina content is correspondingly reduced.

From the first year that I began with the Aluminum Company of America, right after the armistice of the First World War, we felt that one of our important problems was to know how we would take care of the alumina production in case a war should occur. We saw our diminishing supplies of bauxite, high-grade bauxite, in Arkansas. Our company spent a lot of money and developed the bauxite supplies in the northern part of South America, in British and Dutch Guiana. But we also knew there was always the possibility, in case of war, that those would be cut off, and we would have to know what we could do with other things in the country.

As I say, we started in right at the very first, and I figured up—when I knew that you were going to ask me to come here—and found that in our research laboratories alone we had spent something like $5¼ million during the 35 years, on the study of every kind of a process that has been proposed or that we could think of, for the extraction of alumina from clays and other aluminous minerals.

You see, there is actually, in the crust of the earth, about twice as much aluminum as there is iron; but, like iron, a great deal of it, most of it, is distributed in what you would think of as low-grade minerals, from the standpoint of ore.

But we must know what we could do with those. There have been hundreds of processes proposed and patented, and we have investigated the different types.

They really fall into two classes. There are acid processes and alkaline processes.

The acid processes have the fundamental difficulty that all the acids which dissolve aluminum out of clay or high silica bauxite also dissolved iron, and there is no economical process of reducing the iron content of the aluminum solutions or the aluminum oxide satisfactorily to produce the grade of aluminum which we have to have to make these strong aluminum alloys.

We have looked into all of them and we have therefore, ourselves, abandoned the acid processes and gone to the alkaline processes. They rely fundamentally on removing the silica from the clay, or from whatever mineral you use, by combining it with lime. You would have to buy limestone and put the material through a furnacing process with the limestone, so as to combine the lime with the silica, which is the major constitutent of the clay, and leave the alumina in shape where it can be extracted with soda.

So then we have what we call the lime-soda sinter process. During the war, some 5 years before the war, we had come to this conclusion and had gone to work investigating the different stages in that process, because we have the difficulty there that soda in the lime-soda process also extracts a certain amount of silica. That goes into solution and we must remove it very completely before we precipitate our alumi-

num oxide, because we cannot stand more than a small amount, ordinarily about two-hundredths of 1 percent, of silica in our alumina.

We had gone to this primarily from the standpoint of using the large amounts of high-silica bauxite which were still available in Arkansas. I believe that the Bureau of Mines have recently quoted the Geological Survey as saying that there are still nearly 90 million tons of high-silica bauxite in Arkansas in deposits which are more than 5-feet thick.

We had worked out what we call the combination process, which enabled us to take this high silica bauxite and put it through the Bayer process, and extract from it as much alumina as was thereby extractable; then take the red mud, which we would have otherwise rejected and thrown onto the dump, and sinter that with lime and soda, and extract from it most of the alumina and a good part of the soda which we had lost because of the silica, and thus get actually out of this lower grade bauxite substantially as much alumina per ton as we could extract from specification bauxite by the standard process.

We had this process nearly ready for use as the war approached, and when we saw that it was going to be necessary to know what could be done in case of a cutoff of imported bauxite, we spent three-quarters of a million dollars in the operating department, in addition to this $5¼ million that I have already spoken of, in putting this process through a pilot-plant operation on a large scale in our East St. Louis, Ill., plant, using kilns and things we had available; so that when the War Production Board came up with the problem of what they should authorize to be installed as an alternative to the Bayer process on South American bauxite, we were able to show them the results of this pilot-plant operation.

The result was that, in addition to authorizing 1 acid process and 3 alkaline process plants, 1 of them being the Monolith plant and 1 of them being a plant in South Carolina, they authorized us to go ahead and install or build for them in Arkansas a plant, which we built at Hurricane Creek, to use this combination process on these Arkansas high-silica bauxites.

As it turned out, 3 of these 4 other plants were brought to what they would call production and were unsuccessful, or perhaps one of them did not actually ever get into production. The fourth, the Laramie plant was not finished, but has since been operated with technical success by the Bureau of Mines.

Our own picture is that any of these alkaline processes used on that type of material, clay, or anorthosite, can be made to produce suitable alumina, but at a cost which would probably increase the aluminum price maybe several cents a pound.

Our combination process plant was erected in Arkansas and went into production, operated satisfactorily, produced a high-grade alumina, was shut down by the Government after the armistice, and then sold to the Reynolds Metals Co., which has used it ever since to produce substantially all of the alumina that they have made and used in this country, until their New Corpus Christi plant came into production.

We had found that it was economical, the Government-published figures showed it was economical, and we have since built ourselves another plant down there in Arkansas to use the same process, with a

capacity of 400,000 tons of alumina per year. So that we now have in Arkansas these two plants, which can economically employ the high-silica bauxites and produce a high-grade alumina suitable for the production of the metal required to produce the high-strength alloys needed in the aircraft industry.

These plants, while they are at present only using bauxite going up to 15 percent silica, could, with somewhat reduced capacity, employ even a lower grade of material having higher silica.

Senator MALONE. What effect did that have in extending the reserves of bauxite?

Mr. FRARY. It had this effect, that the Geological Survey at the time we entered the war, estimated that we had about 5 million tons of specification bauxite available in Arkansas. They now estimate, as I said, nearly 90 million tons of bauxite available for this process, and there is a large amount of clay right there in Arkansas associated with bauxite, because bauxite is, like clay, the result of a weathering process. The Arkansas clay is really bauxite which is in course of formation, which has been partially weathered.

So this clay could be taken and fed right into these plants with this 89 million tons, or whatever is left of it, and with necessary additions to equipment we could continue to produce alumina in those plants. If we have a stockpile of bauxite which would enable the other alumina plants to operate for a while, while they are putting in some additional equipment, this high-silica bauxite could also be employed in the other alumina plants.

So that we now have reserves adequate for an emergency as long as we do not use them up.

Senator MALONE. How much do you use annually? You say you have 90 million tons there available. What is the annual use roughly of your own industry?

Mr. FRARY. Of the North American aluminum industry, if we take our present production of aluminum, the capacity at the end of the presently scheduled expansion will be about 2 million tons of aluminum; which corresponds with 8 million long tons approximately of bauxite.

So, if all that was produced from just the tonnage of 15 percent silica material estimated by the United States Geological Survey, we would have a 10 years' supply.

Of course, because we wish to conserve this and also because high-grade bauxite is at present more economical in the coastal plants, we continue to import bauxite from South America and from Jamaica, and probably eventually from the Dominican Republic and Haiti. And to the extent that we use that material, we do not have to touch a corresponding amount of this Arkansas bauxite.

Senator MALONE. In peacetime, of course, it is available and it is cheaper. Therefore, it must be used because of the competition.

What you are really saying is that with these hundreds of millions of tons of aluminum clay available in the country, that you know the process, although it is being perfected all the time; that you can use an enormous amount of this material, if you were confined to it?

Mr. FRARY. That is right.

Senator MALONE. And if cost were not the controlling factor?

Mr. FRARY. That is right.

Senator MALONE. So if we are cut off at any time in the future from any, say, even South American bauxite, you could still make aluminum, but it would be more expensive?

Mr. FRARY. Yes; more expensive.

Senator MALONE. That is the point I wanted to be made clear to the committee, because we are talking about our preparations for an emergency and the cost is not the controlling factor there.

Mr. FRARY. Actually, the Government figures during the war showed that the alumina in our Hurricane Creek plant, made from this high-silica bauxite, cost them less than alumina made at Baton Rouge from South American bauxite, because of the abnormal wartime freight rates on South American bauxite.

Senator MALONE. Could the aluminum clays in Wyoming or anywhere, if you are reduced to them, you could use them?

Mr. FRARY. Yes, sir.

Senator MALONE. It would be a matter of expense and cost. If you would go up or down in grade of silica, or whatever the technical term, could you give us some rough estimate of the increase in cost? That is what the committee is interested in, and each one of the substitutes and replacements and in becoming self-sufficient in time of emergency if necessary?

Mr. FRARY. It would be on the order, probably, of 2 to 3 cents per pound of alumina.

Senator MALONE. If you went into very low grade clay?

Mr. FRARY. Yes. One of the fundamental difficulties there is that while we think of clay being everywhere, it is actually very difficult to find a deposit of clay which is reasonably high in alumina, which is large enough at any one place to justify putting in a plant.

Senator MALONE. What about the Wyoming deposits?

Mr. FRARY. The Wyoming anorthosites are large in quantity. That is one of the few places where we have a large deposit.

We spent, I might say, during these years, $2½ million ourselves in geological explorations, looking for large deposits of clay or other aluminous materials which could be used, and also looking for new sources of bauxite in this country and abroad.

The difficulty is that most of the clay deposits are, as I said, small and spotty, low grade. And those that are high grade are already in use and more valuable for the very important production of high-grade refractories, which are needed in the steel industry and other industries.

Senator MALONE. But is the committee correctly informed that there are literally hundreds of millions of tons of clays in the United States that contain alumina, say, from 5 to 35 percent?

Mr. FRARY. Yes. Most of them contain around 10 or 15 percent of aluminum oxide.

Senator MALONE. If you are reduced to using them—and to me the time to prepare for it would be in peacetime, of course you are aimed toward that now—aluminum might cost a little more but you could make aluminum?

Mr. FRARY. Absolutely; we could make aluminum but the cost would increase rapidly as the alumina content of the clay decreased.

Senator MALONE. Any amounts you need?

Mr. FRARY. Yes. And particularly, of course, we would stick to the richer materials available at Arkansas in the beginning until we had

time to build plants elsewhere where there might be an adequate supply of suitable material.

Senator MALONE. But the longer that we have peace—and my own opinion is if we are ready for war we will not have war; that is one of the reasons for this committee—it is only the man who cannot protect himself gets into trouble; nations are combinations of men. You have seen most of them, and I have, too, in wartime and peacetime.

You have told us, I think, exactly what we want to know, that it would be impossible to cut us off from sources that would prevent our manufacturing all the aluminum we wanted, that we would need in any emergency, because you are now so situated, and from what you tell me I think you intend to continue to be so situated, that you are ready to use the stuff you have while you are getting ready to use something else?

Mr. FRARY. That is right. Actually the amount cut off from the Caribbean in the last war was much less than the statements made to your committee.

I have here a letter from our company which handled all that material, and you will find that the actual ship losses were only around 2 percent of the voyages which were made, and the actual part of the bauxite lost was just over 2 percent.

We would have to face, as we did then, the fact that it was necessary to have shipping in the Caribbean to take supplies and men and equipment down there for the bases which the military people had to make. And actually, our shipping which brought the bauxite up also carried down men and materials, most of the men and materials, which were necessary for the defense of that area of the United States.

TRANSPORTATION PROBLEMS IN WARTIME

Senator MALONE. I will say to you, Doctor, without disclosing any classified information—and, of course, the real information is highly classified—that there are some great improvements that would come into effect immediately in repelling any destructive forces against shipping in case of war.

I am not an expert in strategic defense, but we have had a lot of experts before the committee.

Mr. FRARY. I am aware of that. And, of course, one of the factors that gave us trouble in the last war was that all of our own bauxite ships, which were modern and fairly fast, had to be taken by the Shipping Administration for the foreign trade and we were given the old tubs that could only make about 4 or 5 knots an hour, and which were sitting ducks for even the submarines available at that time.

So I think we could still undoubtedly count on a very considerable supply of bauxite from Jamaica, the Dominican Republic, and what you might think of as the northern Caribbean, as well as from Dutch or British Guiana.

Senator MALONE. The testimony this committee has had, I would say is unimpeachable, that you could defend the Western Hemisphere simply because of the geographical situation. So that within that area, then, it is a question of transportation even of short distances over water. But that has been greatly improved because of the methods of defense.

So that what you are giving us today completes the story, as far as the chairman is concerned, in the fact that you cannot possibly, if we can protect North America, you cannot possibly keep us from making the aluminum we need.

Mr. FRARY. That is right.

Senator MALONE. We would like to know that more in detail, but that is the statement that we need to know. This is not the only field in which that is true. We have had some very careless people, careless with the truth, making statements that could be switched around to fit their own ends.

For instance, there was the letter from Harry Dexter White trying to convince the President that you must save the material.

So it is like Mr. Hoover said, and I consider him one of the outstanding mining engineers of the world:

> You and I know that there is enough tungsten in Nevada to run this for 50 years. But the proposition is to get it authentically before the people.

Mr. FRARY. Of course, the difficulty is that many people outside of the industry have not had the facts and have not known the real facts in the case.

Senator MALONE. The facts are easily perverted, just like in the case of reserves. I do not claim to be a mining engineer, although I belong to the AIME and could pose as one, I suppose. We have done lots of mining work but always had a mining engineer with us. The statistics that he quoted were true, but his interpretation was wrong.

It is like a doctor telling me something about a hospital or about his profession. I would know nothing beyond what he told me, and if he told me a fact that I could check, then I would assume everything he told me was correct. But his interpretation could be entirely wrong and I would not know it.

That is just the trouble with people who pervert statistics to sell a bill of goods. That is very dangerous to this Nation. It is not an easy job for the Congress of the United States, as you know.

Mr. FRARY. Yes. One of the things I would like to call attention to in connection with the development of the combination process is that right in Arkansas the processing is being done right at the bauxite mines. We have a minimum of transportation involved. Instead of having to transport tons of bauxite to an alumina plant and rehandle it, we bring the bauxite right into the plant in the same area and ship out only the alumina, thus largely reducing the burden on the transportation of the country.

Senator MALONE. All you say is true, Doctor, and all of us know that know anything about the business, even casually, know that that is true. But the country has been sold for 21 years on the proposition that we are out of bauxite, and that when we are out we will be destroyed. Mr. Ickes—God rest his soul—told us we were out, and that we had to save it, not drill for it but save it.

The fact is that if you save the minerals, save the oil, when war starts you cannot find it in time. Now, with the depletion allowance of oil, it is running out of our ears, like many minerals in production would be if controls were established.

But we would be destroyed from within, as the great President said, President Lincoln, that if this country is ever destroyed it would not be destroyed from without but from within. That is exactly what

has been happening to us. As a result of that have-not policy, as a result, then, of the free-trade policy, we are now dependent upon foreign nations for our strategic and critical materials.

I am now talking about countries across the oceans. There are many things that you cannot get a pound of after war starts.

Those are the dangerous things that are sold to this country by people not like Henry Dexter White and Alger Hiss, but by honest people, who sell it because they have come to believe it. And those are the people we want to reach, Doctor. That is the sole object here this morning, and why we wrote the report. We want to put it in the hands of good, honest people, give them the facts. Get the National Resources Committee report, get the Bell report. The objective was decided before they appointed the committee. That is obvious to anybody who reads it critically. They did not misquote the statistics but perverted them. They always come to the conclusion that we do not have it, that we must shut down and import it, because that is what they want us to do, to start with.

Now, if you look at our report, this thing you are telling us this morning, in your field, is vitally important to this committee.

Go ahead. We do not want to interrupt you. But I do want to impress our objective on anybody who comes before the committee.

If we can just get it out of the hands of the ignorant people—ignorant not in their own business but in yours and mine—that they must study these things and that we must be ready to defend ourselves and to hold our own economic structure, I do not think we are going to have any trouble for 50 years. But we can easily get into trouble and get whipped.

Go ahead, Doctor.

PROCESSES FOR EXTRACTING ALUMINA

Mr. FRARY. The only other thing I have to add, I think, is the fact that aside from the Bayer process, which is the one that is used throughout substantially all the world for extracting alumina, there are only the two processes that have been commercially successful: this combination process I have spoken of and the Pederson process, which was developed by a professor in Norway, jointly, between ourselves and a Scandinavian company, and has been used successfully there under their conditions, and is reported to be successfully used by the Russians under their peculiar economic conditions.

Outside of that, we have had to stick to the Bayer process.

For economic reasons, all over the world men have spent large amounts of money in trying to get aluminum in other ways; we have also the possibility of making aluminum without making alumina, without using our present process. We and other producers have spent a great deal of money on that.

In my statement, I tell you quite a bit about those. I can summarize that by saying that while you can make aluminum in other ways, extracting it from the electrothermally produced aluminum silicon alloys, you cannot do it at a price which would enable you to do it in competition with aluminum made by the present process. At least, that is the opinion of ourselves and others who have had experience with it.

Senator MALONE. When it can be done better that way, it will be done that way; is that not correct?

Mr. FRARY. Yes, when it can be done cheaper and with the same quality product, it will be done that way. But the industry here and abroad has not been unaware of that possibility and has not hesitated to spend large sums of money in attempting to see whether there was an economic possibility of making aluminum by any one of these processes.

The Germans spent a lot of money during the war and we have spent money on it continuously. The Bureau of Mines has spent money on it, the British and French have spent money on it. Our opinion is still that it is cheaper and we get a higher quality product to make it as at present.

Let us assume it becomes cheaper or as cheap to do it any other way; we will be doing it that way, too.

Senator MALONE. As you just testified, yourself, there are certain needs that no other known metal will fill at the present time.

Mr. FRARY. Yes.

Senator MALONE. There are many people who think that now they can perfect or will perfect a process where they can skip the electrolytic or mechanical process. I hope they do, because when they do, it will cheapen the cost. As you say, it can be done, but it does not cheapen the cost.

Go ahead, Doctor.

Mr. FRARY. I think that is all.

I have a few other things contained in my statement, which I would like to have in the record, as to the development of some of these things and the money that has been spent, and especially this question of the Caribbean bauxite experience during the war.

If there is anything you would like to ask about it, I would be glad to answer.

Senator MALONE. We will accept your written statement as exhibit A to your testimony and it will be for reference of the committee, and perhaps parts of it will be published when we publish your testimony.

(The document referred to was marked "Exhibit A" and filed for the information of the committee.)

Senator MALONE. My attention has been called to part of your statement here. You say:

> The aluminum industry in the United States must be profitably competitive under normal peacetime conditions in order to justify and make possible the exhaustive research that is required for the development of new alloys, treatments, etc., for military and industrial application. It cannot be competitive unles it obtains its ore from the cheapest sources which at present are the foreign high-grade bauxite deposits. It would be most harmful to endeavor through artificial means to hinder the unobstructed importation of foreign ore.

Would you go into some detail on that subject, Doctor?

Mr. FRARY. That is connected with my previous statement that we continue to use, for these plants which are located in Arkansas, a certain amount of this low-grade material there, but for the plants which are located elsewhere—for instance, we have a plant in Mobile, Kaiser has a plant in Baton Rouge, Reynolds has a plant at Corpus Christi—for all of those plants it is more economical to use the imported bauxite, and by continuing to do that, we not only save ourselves money but we also permit ourselves to retain for future use the greater part of what high-silica bauxite we have in Arkansas.

Now, there has been agitation in the past for putting on higher and higher duties on many of these raw materials. It would be disadvantageous, for instance, if somebody wanted to put a high duty on bauxite to keep it out, it would in the meantime penalize the industry on our costs. If it made us use up the Arkansas bauxite prematurely, it might make us trouble in case we had to use it for vital purposes.

Senator MALONE. Is that your understanding of what a tariff does, that it prohibits importation?

EFFECT OF TARIFF ON RAW MATERIALS

Mr. FRARY. No; it does not prohibit importation. It tends to discourage the introduction. We have had a tariff of a dollar or a dollar and a half on bauxite, which did not prevent the introduction of bauxite but simply added to our cost of production.

Senator MALONE. Was it $1.50 a ton?

Mr. FRARY. It was a dollar, and I believe at one time it was $1.50.

Senator MALONE. What amount of alumina is there in a ton that would cost you a dollar and a half?

Mr. FRARY. South American bauxite, dried, as imported, carries a little less than 60 percent aluminum oxide. That is about 30 percent metallic aluminum.

So that your duty is multiplied by at least 3⅓ when you convert it to your costs on the basis of the metal.

Senator MALONE. I am intensely interested in this, Doctor, and I think you are touching a very vital subject.

The $1.50 brings into the country a ton of 60 percent aluminum oxide; is that correct?

Mr. FRARY. As a duty; yes.

Senator MALONE. Assuming it was the highest that you know of—and I have no knowledge at all whether it was the proper duty, or represented a differential in cost of wages or anything else, but that could be easily ascertained –you have 30 percent metal in this ton That is 2,000 pounds, is it; or is it a long ton?

Mr. FRARY. A long ton.

Senator MALONE. That is 2,240 pounds of 60 percent aluminum oxide brought in for $1.50?

Mr. FRARY. Yes.

Senator MALONE. That would mean 30 percent metal; is that correct?

Mr. FRARY. In the ore. That does not mean that you get all of it out.

Senator MALONE. How much do you get out?

Mr. FRARY. About 90 percent extraction, in that grade, somewhat better than 90.

Senator MALONE. That would be 672 pounds of the metal, if you got it all out.

Mr. FRARY. Yes.

Senator MALONE. It would be 604 pounds of metal that would cost you $1.50.

Mr. FRARY. Yes.

Senator MALONE. That is aluminum?

Mr. FRARY. Yes; aluminum.

Senator MALONE. Tell me the relationship between aluminum and aluminum metal.

Mr. FRARY. Aluminum is aluminum metal.

Senator MALONE. That would mean it would cost you $1.50 to get 604¾ pounds of aluminum metal?

Mr. FRARY. Yes.

Senator MALONE. And that is still metal when it goes into aluminum proper; is it not?

Mr. FRARY. The aluminum is the metal. That means that it adds about a quarter of a cent a pound to the cost of producing, what you might call the mill cost, the raw material cost, of producing the metal.

Senator MALONE. Yes. It would add about a quarter of a cent a pound to the finished metal.

Mr. FRARY. Finished metal cost.

Senator MALONE. What did you say the price of the metal is now?

Mr. FRARY. About 20 cents.

Senator MALONE. What percentage is that of this one-quarter of a cent of 20 cents?

Mr. FRARY. About 1¼ percent, something like that.

Senator MALONE. About 1 percent?

Mr. FRARY. One an a quarter percent it would be, but it would add up to several million dollars a year which could well be used for further important research work.

Senator MALONE. All right, let us balance that on a matter of, we will say, wages in this country and industry in this country, which would be on your economic structure side, and the matter of security. I am not arguing for this tariff, you understand. I am trying to illustrate to you what in most cases is a very infinitesimal amount, that a tariff, on the basis of very unreasonable competition, makes in the finished product.

I was consultant to the Senate Military Affairs Committee during World War II, and I am the one that sat in with the Japs in signing the charter in the South Seas in 1943. I wrote a report to the committee on manganese, I mean it was included in it.

Everybody that uses manganese is for free trade in manganese. As you know, the habit that we have in America is that we are for free trade on the things we buy and are for a tariff on the things we sell. And being all for that, we leave ourselves liable then to being destroyed economically by people. You probably read the paper and you know what is going on on that score.

Mr. FRARY. Yes.

Senator MALONE. And in New York we have a foreign trade conference with some great speeches by some great men, and we throw our markets wide open.

I am talking about a principle. And that is the reason why we are dependent on others for manganese and why we cannot get many of these things that are vital.

We have to make up our minds sometime, and it has nothing to do, from the standpoint of security, with limiting wages, and things like that, in this country. If you carried this free trade thing through to a logical conclusion, you would find there is nothing, not even a Ford automobile, that cannot be manufactured cheaper in some other country, using our methods and our supervision, with the tariff.

Article I of the Constitution says, in section 8, that the Congress of the United States shall regulate foreign trade, et cetera, and you

have had some people who want to change the Constitution of the United States and transfer all that responsibility to the Executive.

You are familiar with that; are you not?

Mr. FRARY. Yes.

Senator MALONE. The State Department has proceeded since that time to distribute the markets of the Nation to all the nations of the world. So it has cost us $260 billion for this prosperity for 20 years. You had PWA and WPA and two World Wars, and Korea, and preparation for war. Perhaps some of these people could tell us how long we can dig up that money, ten or twelve or fifteen billion dollars, to go out every year to make up the difference here.

Now we have a policy, a short amortization period, guaranteed unit prices. It applies to copper. I just have not inquired about it, but there are so many things where we try to sustain something by doing something else that is uneconomic. If we keep going off into space, I do not know just where we are going to land.

I would like you to read a little paragraph in this report some time, which is just as true now as it was then, that manganese, while it might take a tariff to keep you in business in this country, to the extent that you could do like in your oxide clays, you could go right on if you were cut off; that the manganese and steel was considerably like the soda in the biscuit, that it did not make much difference whether it was a 10-cent package or a 50-cent package, the soda did not change the price of the biscuits much.

You find that true in so many things.

Now we have an argument for copper to be put on free trade. They are about as interested in copper in South America as we are here in the United States, and nobody else can get the copper business because of that switch back and forth.

You and I are older than most of these people here, Doctor?

How old are you?

Mr. FRARY. Seventy.

Senator MALONE. I am 64. So I have seen all of them come and go. And it seems to me we have to talk about a principle, first of security and, second, of our economic structure. So I am very much interested in what you have just carried to a conclusion as to what it would mean actually, the 1 percent, in the process, trying to protect American labor and investments.

Mr. FRARY. Of course, if you wish to remove all foreign bauxite importation, that would mean you would use up what we have here in this country in a very short time.

Senator MALONE. It would not remove it at all.

Mr. FRARY. You would not protect the industry unless you hindered the importation and you do not protect our bauxite reserves if you prevent the importation.

Senator MALONE. You see, we have free trade on copper for the same reason, and that is your competitor. Why not put a principle on both of them? Then your competitor is meeting the same thing and meeting the national security.

Mr. FRARY. Of course, our competition is not only in copper but everything else that the man wants to buy.

Senator MALONE. What is it?

Mr. FRARY. Steel, stainless steel, tin, zinc, lead, paper.

Senator MALONE. All that material that you can probably produce in this country. I think you would find you would be just as well off if you had a principle that protected the security and the economy of the country.

Your argument is very powerful with me and it is because you believe it yourself, and you are experienced. You have spent your life in this business.

You are going to continue to have your security threatened unless you can continue the way you are now. I just refer you back to the report that you have in your possession. There is only one way to go if you do not have any protection which is provided for by the Constitution of the United States.

There is a Malone bill providing a subsidy for tungsten, manganese, chromite, and several other little things which you do not need at all if you have the principle of protection. It has cost a lot of money. So you pay for it one way or the other. But when you adopt a substitute, which we are very definitely doing through shorter amortization periods and so forth, we are getting almost as bad as the Russians. We will be manipulating our currency like they do.

Mr. FRARY. That is what Roosevelt did. He went off the gold value and confiscated 40 percent of everybody's savings and insurance and so forth.

Senator MALONE. You are correct. But why did we take his other programs? We take them because it is profitable to our country. There are two methods of approach to destroy this country; there is the political and the economic. The political is being argued over here now.

It did not start yesterday, it started with the recognition of Russia in 1933. The economic approach to destroy our structure is more dangerous now than anything else. There is your economic structure and your 1934 trade structure on which you are arguing, where you got free trade in the first place. The State Department believed everything you are saying, except that they believed it about everything, while you are just talking about aluminum.

So we cannot straddle the fence; we cannot root for the structure on the one hand and against part of the structure on the other. You and I will agree on that.

I would like to say I am not doing all this for the Aluminum Company of America or the miners of Nevada or the textile people of New England. I am doing it for the United States of America, for my grandchildren. We are not interested so much in your company as a company but we are interested in the success of the country, in adding to the security of this Nation and our economic structure. And I speak my mind about it every time I get up, on the Senate floor, in Nevada, in your State, and everywhere else.

I would like very much for you to do some thinking about it. This is a matter of record, and you cannot put free trade on bauxite and put a tariff on everything else. If you are a free trader, you are a free trader, and you have to carry it to a logical conclusion.

The people up in Maine, God bless them, the woolen manufacturers, passed a resolution at their last annual convention asking for a tariff on cotton. Of course, that would put them on a good basis. At the same time, they asked for free trade on wool. This would put the wool growers in Australia out of business, because it costs 25 percent more to raise sheep in Australia than it does in the United States.

That is the economic question. You had your finger on one angle of it, but not on the real question. The real one is what I am telling you. And you will find that in the second recommendation, if you will just open the book. You should go back to the Constitution of the United States.

I appreciate very much your appearance here, Doctor. I believe that you are the kind of American that can do this job.

Mr. FRARY. Thank you.

Senator MALONE. But we have to agree on a principle.

I think when you give it some thought you will agree on that.

Mr. FRARY. Thank you, Mr. Chairman.

(The following statement was subsequently received for the record:)

STATEMENT BY FRANCIS C. FRARY, TECHNICAL ADVISER, ALUMINUM RESEARCH LABORATORIES, ALUMINUM COMPANY OF AMERICA

I am Francis C. Frary, Technical adviser to Aluminum Research Laboratories, Aluminum Company of America, at New Kensington, Pa. From December 1918 until January 1952 I served as the director of research for the company, which I shall refer to hereafter as Alcoa.

I am testifying at the invitation of your chairman, extended by letter dated August 13, 1954. By means of this letter, Senator Malone asked that I make any comments which might be appropriate to the hearings of this committee on the subject of substitutes, replacements, and synthesis of critical materials required by the United States in time of war.

In response to that invitation, I should like to point out that the aluminum industry is a relatively new one, in comparison with those involved in producing most of the other familiar metals of commerce. Just 65 years ago aluminum was more or less a laboratory curiosity. It had no established uses.

It can be said, therefore, that the history of aluminum is one of substitution for other materials. In very few instances did markets exist for this metal. Instead, markets had to be developed or created. Users had to be convinced of the superiority of aluminum for various applications. And it was vitally necessary that aluminum, in order to find markets, be made available at a price which was competitive. Otherwise the aluminum industry could not have survived.

The aluminum industry is one which has undergone tremendous growth in recent years. There is no good reason to doubt that it will remain a growth industry for many years to come. Its present size, together with its projected growth pattern, should be a considerable reassurance to this Nation that the aluminum supply can be expected to stay well ahead of demand.

In the short space of time between 1939 and 1953, the aluminum industry's capacity to smelt primary aluminum in the United States rose from 327 million pound annually to more that 2½ billion pounds annually. That represents a rise of nearly 800 percent. Upon the completion of presently announced expansion programs by the industry in the Untied States, the annual primary aluminum smelting capacity is scheduled to rise to a total of 2,890 million pounds, all of which can be classified as commercially economical production.

This does not include any of the production of the aluminum industry in Canada. In 1953 production of Canadian primary aluminum facilities amounted to more than 1,091 million pounds. All told, the North American producers will have smelting capacity sufficient to provide 4,145 million pounds of primary metal each year upon completion of presently scheduled expansions. In addition to this, I understand that the Canadian producer has long-range plans which will boost the ultimate capacity of North America's primary aluminum producers to 4,990 million pounds a year. That would be more than 15 times the capacity of the United States in the early years of World War II.

My purpose in citing these figures is to show that certain testimony previously given before this committee to the effect that aluminum is still a "scarce material," has probably been based on misinformation. I also feel, and I am sure that I am reflecting the feeling of our company, that the records should be set straight concerning Alcoa's early and continued interest in all processes for extracting alumina from low-grade bauxite, laterite, shale, alunite, clay, anorthosite, and other aluminous materials. All of these are materials which contain more or less alumina, or aluminum oxide. Alumina, of course, is the refined

material from which aluminum metal is produced by the electrolytic process. It is the basic raw material used in the smelting of primary aluminum.

It is most important, for a full understanding of the aluminum industry's basic problems, that the history of the use of bauxite be explained. As I have stated, the aluminum industry has never had readymade markets. It has always had to complete for them. The competition usually has been against other well-established materials. It has therefore always been necessary to produce aluminum as economically as possible.

From the beginnings of the aluminum industry the cheapest alumina has always been made from high-grade bauxite by the Bayer process. It is natural, therefore, that bauxite has always been the basic ore of aluminum. On the other hand, the American aluminum industry has always been keenly aware of the fact that supplies of domestic high-grade bauxite are limited. Since the early days of the industry, therefore, our management has always recognized the importance of research aimed at finding economical ways of using lower grades of bauxite and other aluminous materials such as clays.

As I was director of Alcoa's research laboratories from the end of World War I until January 1, 1952, I believe I am in a position to testify authoritatively about the facts on Alcoa's attitude toward processes for the production of alumina from other materials than high-grade bauxite, as well as the company's long-range attitude toward new alumina processes.

When I came with the company, the cost of the two pounds of alumina required to make one pound of aluminum was such a large proportion of the total mill cost of such production that it was evident a reduction of the cost was one of the important objectives of the newly established research organization. In the first years of the existence of the research group we began work on the Bayer process for purposes of cost reduction, and on processes for extracting alumina from clay.

Continued research and development work by the laboratories of Alcoa, and by the operating department, has resulted in a nearly 50 percent reduction in alumina cost. This was a major factor in enabling this company to avoid a price increase on our metal. Actually, we made several decreases in the price of pig aluminum, in spite of the steady increases in wage rates and costs of materials and freight. The price per pound fell from about 33 cents during World War I to a low point of 15 cents during World War II.

Naturally, economies due to increased production and technological improvements in the process and equipment for converting aluminum oxide into metal also played an important part in reducing costs. I might point out that the smelting plants built for the Government during World War II by Alcoa, as well as our own newer plants, involved all our latest improvements and were more modern and efficient than any previously in existence.

You could make alumina out of a red building brick if you were willing to pay the price—just as you could make iron out of it. But it goes without saying that it is unreasonable to try to do so commercially. Any company that is going to invest millions of dollars in alumina plants would be doing the Nation (as well as its stockholders) a disservice if it did not build its most economical processes into such plants.

As I stated, the question of an economical supply of alumina has always been prominent in the minds of our company management and research staff. In addition to our own research investigations, we have followed all of the patent literature and other scientific papers; and we have considered a great variety of processes proposed by outside inventors. In each year we have spent considerable sums of money in the study or development of processes which looked promising for either the production of alumina from minerals other than high-grade bauxite, or the production of aluminum from other materials or by new processes.

Alcoa, as the pioneer company in the aluminum industry, at first used Arkansas bauxite for the production of alumina. Then, as more information was acquired as to the limited nature of the ore reserves in that State, we explored the availability of high-grade bauxite abroad. As you know, today a considerable proportion of our high-grade bauxite supply somes from South American mines.

Since the beginning of World War II, Alcoa has spent over $2,500,000 in exploration, drilling and analytical work, on the investigation of the occurrence of sources of alumina other than high-grade bauxite. These include the low-grade bauxites and bauxite clays of Arkansas, Mississippi, Alabama, and Georgia, the diasporic clays and flint clays of Missouri, and Pennsylvania, the high alu-

mina clays in Washington, Oregon, and California, and the alunites and laterites of the Western States.

In addition to this geological exploration, Alcoa has, in all, during the last 35 years, spent over $5¼ million in studying and developing various processes for extracting the alumina from these other materials. I am not including in this figure the cost of a pilot plant erected during World War II at East St. Louis, or the costs involved in an unsuccessful attempt to commercialize one of the processes.

It is well to note that there are only two processes known to date which have been commercially successful in producing alumina in competition with the Bayer process extraction from low-silica bauxite. The first one of them to be developed was the Pedersen process, which will be referred to later; the other is the combination process.

The latter process, developed by Alcoa, was the direct result of our years of study of the problem of economically extracting a satisfactory grade of alumina from minerals containing aluminum silicates. Since silica present in the mineral involved expense in the extraction of the alumina it became evident to us sometime before the Second World War that the most economical material to treat by a new method would be a bauxite containing somewhat more silica than was economically advisable in the regular Bayer process. The domestic reserves of high silica bauxite have always been recognized as being very much greater than the reserves of low silica bauxite, and with their higher alumina content, as compared to clay, there was an incentive to develop an economical process for the use of this domestic raw material.

After we had come to the conclusion that, in the present state of the art, acid processes would not only be too expensive but would also produce alumina of insufficient purity, we concentrated our attention on the alkaline processes. The result of several years of work was the development of the combination process, for treating bauxite containing up to about 15 percent of silica.

We had put this through the pilot-plant stage of operation in improvised equipment at our East St. Louis alumina plant in time so that when the War Production Board had to face the necessity of providing additional alumina plant capacity to extract alumina from some mineral other than low silica bauxite, we were able to show such convincing results that the Board authorized Alcoa to construct and operate for them the Hurricane Creek Plant in Arkansas to use this process, and to install equipment at our East St. Louis and Mobile plants, and at the Government-owned Baton Rouge plant so that, if necessary, these plants could also use high-silica bauxite.

Four plants, to use other processes and raw materials, were also authorized by the War Production Board at a cost of several million dollars each. Three of them were completely unsuccessful and the fourth (the one at Laramie) was not completed at the end of the war but has since been operated with some technical success by the United States Bureau of Mines.

Our Hurricane Creek plant operated successfully and economically from the start and made high-grade alumina.

This latter plant was leased by the Government at the close of the war to Reynolds Metals Co. and later sold to that company. Subsequently it produced substantially all of the alumina used in all their plants until very recently. In order to facilitate the sale of the Government-owned alumina plants, Alcoa granted to the purchasers of a free license under its patents on the combination process.

Needing additional alumina capacity, Aluminum Company of America has recently built another plant in Arkansas, near the town of Bauxite, to use this same process on high-silica bauxite. This plant is in regular operation producing about 400,000 tons of alumina per year.

The combination process is so called because it combines the Bayer process (in which alumina at least equal to the weight of silica is discarded into the red mud waste) with a lime-soda sinter of the red mud, extracting sodium aluminate by leaching the sinter, and charging this solution back into the Bayer process for desilication, so that all of the alumina produced is Bayer process grade. These sintering and leaching steps (which are fundamentally the same as in the Monolith process previously discussed before this committee) were proposed for siliceous materials as far back as World War I; but desilication by returning the liquid to the Bayer process, which made the process produce a satisfactory quality of alumina, was new.

The other commercially successful process of extracting alumina from bauxite (preferably low silica) was invented by Prof. Harold Pedersen of Trondhjem,

Norway, and developed jointly by our company and an affiliated company. It is economically successful under Norwegian conditions, and has also been reported to have been used rather extensively in Russia, and may be applicable either alone or in combination with the Bayer process in treating the high-iron laterites of the Pacific Northwest. It involves electric furnace smelting of a mixture of the aluminous material with lime and coke, with or without the addition of iron ore, to form cast iron and a calcium aluminate slag. The slag is leached with sodium carbonate solution, and aluminum oxide precipitated from it. We spent over $450,000 in the development of this process.

In the previously mentioned $5¼ million spent by Alcoa's research staff, there is included a considerable sum spent on the development of a suitable process for treating the northwestern laterites. Work on this process was carried through a pilot plant scale to the point where we have the necessary data for building a plant to treat these ores if an emergency, such as war or other changed conditions, should make the construction of such a plant advisable.

Another process, capable of treating high-silica bauxite, upon which Alcoa's Mr. Charles Martin Hall (inventor of the electrolytic process of producing aluminum) had spent a good deal of money before his death in 1914, and which had been abandoned then because the product was unsatisfactory, is called the dry process. In this process, high-silica bauxite or a mixture of bauxite and clay is smelted with coke in an electric furnace at a very high temperature, and the impurities are reduced to form a metallic alloy containing iron, silicon, aluminum, and titanium, leaving the purified alumina in the form of a molten slag.

We took up this process again in 1923 and were successful in producing an alumina which could be used for the production of aluminum having a purity greater than 99 percent. In 6 years of work, which gradually progressed to semicommercial operation of this process, we spent over $900,000 (net after giving credit for the alumina produced) and produced many hundreds of thousands of pounds of alumina which was used to make metal. At a time when the Aluminum Company of Canada was still a subsidiary of Alcoa (which has not been the case since 1928) we installed this process at the plant which we built in Arvida, Quebec, and it was used for several years but eventually was abandoned for commercial reasons.

During 5 years, beginning in 1920, we spent over $700,000 on the development and large-scale operation of a process for producing aluminum from high silica bauxite or a mixture of bauxite and clay by making dry process alumina, smelting it with copper to form an aluminum copper alloy, and electrolytically refining this alloy in a fused salt bath. Many hundreds of thousands of pounds of this metal were produced and used, but the process turned out to be uneconomical.

In the 5 years beginning in 1927, we spent over $230,000 in the electrothermal reduction of aluminum silicate ore to produce aluminum silicon alloys containing 20–50 percent aluminum. In the course of this work we also developed the electric furnace process for producing metallic silicon by smelting pure quartz, and found that it was commercially more desirable and cheaper to produce pure silicon in this way and pure aluminum by the regular process, and alloy them as required, rather than to smelt a silicate and produce a rather impure aluminum silicon alloy. The electrothermal production of pure silicon then became a regular commercial practice with us.

In 1939 we found that pure aluminum could be extracted from the electrothermally produced ferrosilicon aluminum alloys by heating them with aluminum chloride or fluoride, and cooling the resulting vapor. Work on this process was interrupted for nearly 5 years during World War II, but between 1939 and the end of 1951 we spent over $650,000 on laboratory and pilot plant work with it. It was eventually decided that technical difficulties in the process made the cost picture so unfavorable that it would be impossible to use it, and the work was stopped.

The extraction of aluminum from the electrothermally produced aluminum silicon alloys (preferably very low in iron) by the use of molten zinc or lead, and the recovery of supposedly pure aluminum from the resulting alloy, has been the object of invention and propaganda by several foreign inventors, and considerable experimental study abroad and by the Bureau of Mines in this country. During the years 1942 to 1944, inclusive, we spent a considerable sum in the investigation of the basic facts involved in these processes, and concluded that it was impractical to make a satisfactorily pure aluminum with them at a cost which would be competitive with the present process.

As mentioned previously, during the last 35 years we have spent over $5¼ million on these processes, not including the cost of the combination process pilot

plant at East St. Louis or the costs involved in the unsuccessful commercialization of the dry process in Canada. Thus it is clear that we have not only been always alert to the problems posed by the necessity of having low silica bauxite available for the commercial Bayer process of producing alumina to be made into metallic aluminum, but have never hesitated to spend large sums of money in investigating all possible alternatives.

There has been some testimony before this committee concerning losses of bauxite-carrying ships and escort vessels in the Caribbean during World War II. While I have no personal knowledge on this subject, I would like to offer for the record a copy of a letter, written by Mr. William C. White, president of Alcoa Steamship Co., a wholly owned Alcoa subsidiary, on the above subject. I believe the letter, which is appended to this statement, will clarify a number of misconceptions and erroneous conclusions which have previously appeared in the record.

The aluminum industry in the United States must be profitably competitive under normal peacetime conditions in order to justify and make possible the exhaustive research that is required for the development of new alloys, treatments, etc., for military and industrial application. It cannot be competitive unless it obtains its ore from the cheapest sources, which at present are the foreign high-grade bauxite deposits. It would be most harmful to endeavor through artificial means to hinder the unobstructed importation of foreign ore.

Furthermore, the combination of factors which could totally shut off foreign supplies is remote. The importation of bauxite also permits us to conserve our domestic supplies against the time of need. Nevertheless, we must be at least technically prepared for a partial or total shutting off of such supplies during an all-out war, to the extent of knowing what we could do if necessary with domestic sources of alumina including not only high silica bauxite but nonbauxitic materials.

There is still a large tonnage of high silica bauxite in Arkansas. The alumina plants outside of Arkansas could, if necessary, handle a limited amount of high silica bauxite mixed with low silica bauxite from the stockpile, with no great reduction in capacity. A stockpile of enough high-grade bauxite to permit such operation during the time required to install the additional equipment necessary for treating high silica bauxite would insure the industry's continued production. Great progress has been made in the establishment of such a stockpile.

To sum up: The North American Continent must continue its heavy dependency on high-grade imported bauxite. Concurrently, national security requires that we continue research toward finding and using acceptable domestic substitutes.

ALCOA STEAMSHIP CO., INC.,
New York, N. Y., November 3, 1954.

Mr. I. W. WILSON,
President, Aluminum Company of America,
Pittsburgh, Pa.

DEAR MR. WILSON: Following our recent conversation on the hearings of the United States Senate Committee on Interior and Insular Affairs, I have looked up the records of vessel sinkings in the United States bauxite trade during World War II. I find that information which has ben furnished the committee to date is such that erroneous conclusions might be drawn from it.

The facts are as follows: Between Pearl Harbor Day and V–E Day, there were 915 sailings (northbound and southbound) and 26 vesels lost by enemy action. The vessels lost, therefore, were 2.9 percent of the sailings. 3,549,609 tons of bauxite were brought to the United States, and 74,455 tons were lost with the 26 vessels which were sunk. The bauxite lost, then, was 2.1 percent of the bauxite landed in the United States.

Soon after Pearl Harbor Day, the Maritime Commission, through the War Shipping Administration, took over al American-flag vessels and reassigned them to those ship operators who could best use them in the trades which War Shipping Adminstration wanted covered. Because the Alcoa Steamship Co. vessels were relatively new and fast, almost al of them were assigned to worldwide trades, and we were given older, smaller, and slower vessels with which to move the bauxite. Many of these had a speed no greater than 4 knots, and seldom did they have a speed greater than 10 knots. This slow speed, of course, contributed materially to the number of sinkings.

The southbound sailings of our fleet during this period of time handled a large percentage of the supplies and equipment needed for building the Army.

Navy, and Air Corps bases which we were in the process of establishing in the Caribbean. Without the service of the bauxite vesels southbound, other ships would of necessity have been forced into service to supply the material for these bases.

Sincerely yours,

ALCOA STEAMSHIP CO., INC.
WILLIAM C. WHITE,
President.

CONTRIBUTIONS OF RESEARCH AND ENGINEERING TO THE CONSERVATION OF CRITICAL MATERIALS

Scientific research and closely coordinated engineering development have led in the Bell Telephone System to significant savings in the consumption of strategic and critical materials and may be expected to bring about further economies in the future. These benefits are the result of long-range studies in electrical communications, chemistry, physics, and metallurgy and the new knowledge, inventions, and technological developments that have followed. The effective collaboration of engineers responsible for product design and manufacture has contributed to the full realization of the fruits of the research.

It is well known that much of the fundamental research in the physical sciences that has given rise to modern industrial progress has been done in the universities. Manufacturing industries have devoted increasing efforts mainly toward product development and both university and industrial laboratories have carried on large programs of contract research and engineering work for the Government. In the course of these several research and development activities, much new information and many new products have been developed which have alleviated the drain upon our strategic and critical materials. Notably in the field of organic chemistry, synthetic plastics and elastomers made from abundant raw materials have provided useful substitutes for scarce metals and imported organic products, such as natural rubber, resins, and oils.

Large users of materials have been in a particularly good position to make and suggest to others how to make important economies in the use of critical substances. First of all, the user's philosophy of getting the most out of materials leads him to be concerned about the performance and stability, as well as the cost and availability of materials. For example, the Bell Telephone System, a large user of materials, supports in its laboratory organization a long-range program of research in chemistry and metallurgy for the purpose of acquiring and maintaining a background of information necessary in the intelligent use of the raw materials and products of commerce. These studies have lead over the years to a better understanding of the processes of corrosion and deterioration and how to obtain satisfactory performance and long life. Knowledge of why materials behave as they do has made possible the selection of the most suitable materials for given purposes. Furthermore, such knowledge has given rise to the synthesis of new compounds and alloys better suited for special needs. New kinds of materials, often with unique properties, are required for the new devices and systems that grow out of physical and communications research.

The long-range future trends in the communications business appear to be in the direction of the replacement of electromechanical systems with electronic devices and introducing progressively greater miniaturization of components as transistors replace vacuum tubes. One can expect wider use of magnetic oxides, titanates, silicon, germanium and other compositions of matter as circuit elements in place of systems employing more cumbersome components and circuitry. The result of this may be a marked reduction in the volume of materials used, as well as large savings in many of the more critical materials, such as copper, nickel, lead, tin, etc. The following examples will illustrate this trend.

One of the most spectacular reductions in the use of a critical material has been in the case of copper. In long-distance transmission, 50 years ago it required 350 pounds of copper per mile of voice circuit; this was reduced to 54 pounds in 1917, to 7.3 pounds in 1938, to 3 pounds in 1948, and 1 pound in the new L–3 carrier system of today. In the radio-relay system that now spans the continent for long-distance voice and TV transmission, no copper is used between the towers. This remarkable reduction in the consumption of copper is the result of technological advances growing out of telephone research.

Lead is one of the common metals in short world supply. One of its largest uses for many years has been for sheathing telephone cables for which purpose

it is hardened with 1 percent antimony. In addition to the scarcity of both lead and antimony, there have been certain technical limitations that have encouraged a search for a more suitable sheath. When polyethylene was discovered, it was immediately considered for this purpose. This useful plastic is obtained by chemical synthesis from ethylene gas derived from petroleum. Before it could be employed as cable sheath, it was necessary to learn how to assure its chemical stability and improve its physical properties. These studies were successful and at the present time a half of the cable production for Bell System is covered with polyethylene with large savings in lead, as well as antimony. This replacement trend is expected to continue until telephone cables are no longer sheathed with lead.

Another promising development in the cable field relates to the extrusion of aluminum. A scientific study of the flow properties of this metal has led to learning how to extrude it at moderate pressures and temperatures without damaging the paper used for insulation of the wires and cores.

An electrochemical study of storage batteries, employed in the telephone plant as a standby power source, led to the conclusion that the standard lead-antimony alloy used for the grid structure is in some respects technically unsound resulting in unnecessarily rapid deterioration, self-discharge and excessive power loss. It was found that 0.06 percent calcium could be substituted for 8 percent antimony as the hardening agent to produce batteries that in telephone service last more than twice as long and have but a fifth of the power loss as compared with antimony lead batteries. As a result of this substitution, these benefits have been realized and in addition an annual saving of 200,000 pounds of antimony, a strategic material, has been made.

Precision carbon-film type resistors consisting of carbon deposits on a ceramic base were introduced during World War II and have increasingly replaced wire-wound resistors with substantial savings of nickel and chromium from which resistance wire is made, as well as industrial diamonds required in wire drawing. Carbon-film resistors were first used on a large scale in the Western Electric Co.'s production of the M–9 gun director, where, had wire-wound resistors been required, the demand for resistance wire would have overburdened American wire-drawing capacity.

Nickel has been widely used in the communications industry in magnetic alloys, nickel silver (an alloy of copper, zinc, and nickel without any silver in it), nickel chrome steels and in electroplating. Metallurgical studies, together with product and manufacturing engineering, directed toward the development of substitute materials have been successful in reducing the consumption of nickel in the Bell System by 65 percent. It was found, for example, that the nickel content of nickel silver, widely used for spring stock, could be reduced from 18 to 12 percent. The data supporting this development were made available to all manufacturers with the result that the 12 percent alloy has completely replaced the old material for most uses. In the Bell System alone, the nickel saving resulting from the use of this alloy is nearly 300,000 pounds a year. In the magnetic materials field, it has been possible to save a similar quantity of nickel by finding out how to use silicon steel in place of certain nickel-iron alloys. Continuing research on magnetic alloys and magnetic oxides known as ferrites may be expected to lead to further reduction in nickel requirements. Ferrites are particularly suitable for high-frequency applications and for components in miniaturized systems in military weapons and devices.

Electrical capacitors can now be made by depositing two one-millionths of an inch of zinc on a lacquer film one ten-thousandth inch in thickness, replacing 2 layers of aluminum foil, each of which is 85 times thicker than the zinc film. Here again the advantage of miniaturization is realized and brings about an overall reduction in size of apparatus with economies in the use of materials, some of which are on the critical list.

Among steps that have led to the conservation of tin are the substitution of electroplating for hot dipping in the tin coating of wires and the reduction in the use of solder for cable joining and wire connections. Electroplating uses but one-third the amount of tin required in hot dipping. A tool has been developed for making solderless wrapped connections by purely mechanical means and is now going into use and making savings in the use of tin that will eventually exceed 75,000 pounds per year.

Quartz crystals can now be grown in the laboratory under high pressures and temperatures and we believe can be produced commercially for use in the electronics and communications industries, and compete successfully with Brazilian

natural quartz which until now has been the only source of this essential material. Crystals of suitable size (about one-half pound) can be grown in 30 days.

Corrosion of metals costs this country $6 billion a year, if the cost of protective measures is included. While it is impractical to prevent all economic loss caused by corrosion, it does not seem unreasonable to expect that greater research effort in the field of corrosion control could lead to a 10 percent improvement with an annual saving of more than a half billion dollars and thousands of tons of critical metals, such as nickel, tin, lead, and aluminum. We believe that our own efforts in this field have saved the telephone industry many millions of dollars and have contributed a great deal to the development of methods of corrosion control used by others. Our work has taken the form of investigations of the nature of the chemical reactions of corrosion and the development of methods for measuring the effectiveness and quality of coatings for protection against corrosion. Here, as in other research projects, an essential step has been to devise means for measurement and evaluation. In the field of corrosion protective coatings, more precise methods of measuring coating durability have guided the development of products of improved quality and consequently have led to the saving of materials.

Research of very fundamental nature on semiconducting solids led to the discovery of the transistor. In this type of device, which performs many of the functions of a vacuum tube, a piece of germanium (or certain other substances) little larger than a pinhead is the essential part. This invention, one of the most important in the field of the physical sciences in many years, is having far-reaching effects. In addition to greatly extending electronic technology, the transistor is giving rise to the miniaturization of electrical components and circuitry with the saving of many important materials, including nickel.

One of the many interesting byproducts of transistor research has been the invention of the silicon solar battery which converts the sun's energy directly into electrical energy. The efficiency of this conversion is now 8 percent and there is prospect of doubling this. Even now this solar battery is more than tenfold more efficient than any other method for the direct conversion of the sun's energy into electrical power. While this is in a very early stage of development, we have plans to use it to supply power at remote stations and thereby save the expense of constructing power lines and the use of copper or aluminum that would be required. Incidentally, the element silicon, the essential part of the solar battery, is the most abundant metal in the earth's crust. It has required considerable research, however, to obtain the very high purity required for this application.

The need for semiconducting materials of extremely high purity has led to the invention of a purification process known as zone refining. By this technique, it has been possible to produce materials in which the significant impurities are less than 1 part in 10 billion—probably the highest purity level ever attained. A metallurgical study of one of these ultrapure materials has led to the discovery of a type of structural defect that may account for the fact that the strength of metals is but a fraction of that predicted from theoretical considerations. It is well known that high purity often improves the chemical and electrical properties of metals and it seems reasonable to imagine that a higher order of quality might be obtained if these structural defects, as well as impurities, can be eliminated, minimized, or made use of by maintaining at controlled levels. Research in these fields could lead conceivably to such improvements in the performance of some of the abundant materials as to bring about considerable reduction in the demand for some of the materials on the critical list.

In general, it can be said that research has led to the solution of most of our materials scarcity problems and, in addition, has yielded unexpected rewards in the form of new discoveries and inventions. Often a substitute material or design has proved better than the original. New knowledge has led to new art that in turn has given rise to improved telephone service.

The foregoing illustrations of how research has contributed to savings in the consumption of critical materials pertain to one single but large industry. On a basis of this experience, it seems clear that it would be in the national interest to bring about a larger volume of research of long-range character. Continuing programs of basic studies should lead to the discovery of new scientific facts and phenomena upon which future progress in technology must depend. Out of such research will grow also the knowledge of how to use our natural resources more intelligently and how to become less dependent upon many of the critical and strategic materials.

R. M. BURNS.

Nickel Conservation in the Bell System

When you pick up your telephone and dial a number, your finger points directly at Bell System nickel conservation and substitution achievements.

Just below your fingertip on the dial number plate, for instance, is a ceramic coating and under the coating is a layer of nickel placed there in manufacture to help the ceramic material adhere securely. Hidden more deeply in your telephone instrument are more than 2 dozen parts in which nickel is important.

Beneath the receiver cap next to your ear is an assembly of sound-producing parts. Some of these are made of permalloy, a nickel alloy with special magnetic properties developed by the Bell Telephone Laboratories specifically for use in the telephone plant. Permalloy is also at work in the armature in the base of your combined handset.

As you dial your number, contact springs of nickel silver go into action in the dial mechanism. The pulsating flow of electric current between your instrument and the central office activates relays in the far-off office. These switching devices, which automatically connect you with the party you want, have springs made of nickel silver. They are used by the millions in the Bell System. As many as 50 to 100,000 relays may be installed in a single large crossbar exchange.

Your voice makes its electrical journey through the complex telephone network at the speed of light and is reproduced by the distant receiver with clarity, strength, and naturalness. To achieve this remarkable result—a result so commonplace that Americans rarely give it a second thought—your voice is helped in its travels by such devices as loading coils which, among other tasks, reduce signal distortion. The cores of these coils are made of permalloy.

The successful trip your voice makes is dependent, too, upon the services of innumerable electronic tubes—of which, in all the Bell System, there are approximately 1½ to 2 million. There is nickel in various parts of all these tubes.

* * * All of which is an incomplete, even sketchy, picture of the uses of nickel in the Bell System. Actually, the metal has become so completely integrated into the telephone system that it is virtually impossible to find apparatus in which nickel is not playing a significant role.

THE NATIONAL NICKEL SHORTAGE

Some of the same properties which make nickel practically indispensable to the Bell System—itself a national defense asset—make nickel indispensable to the national defense efforts of other industries.

Defense requirements for equipment and material cannot be met satisfactorily without nickel. The aircraft industry, for example, uses alloys of high nickel content in building all types of motors including jet engines and rocket motors. Large quantities of special nickel steels are also needed by the chemical and petroleum industries for the expansion of defense supporting facilities.

The demand for nickel in 1952 in the United States, according to the National Production Authority, is about double the available supply and the situation is likely to get worse before it improves. Consumption of nickel this year for civilian and military purposes will probably be greater than in any year since 1948 when about 187 million pounds were used, of which only a small amount was devoted to military production. Since that time military requirements have increased precipitiously and civilian allotments have been cut drastically. It is estimated that in 1952 less than 80 million pounds of nickel will be available for civilian purposes.

How does the Bell System fit into this picture?

The current nickel shortage was first anticipated about the middle of 1950 and the Bell System launched a program immediately to cut down the amount of nickel used in the system. In 1952, 1,888,100 pounds of nickel are called for to do the Bell System manufacturing job, and about one-third of the requirement will be obtained from scrap saved by the Bell System.

This quantity reflects recent substitution and conservation efforts. Since 1950, the Bell System has reduced its annual requirements for nickel by 984,000 pounds—or about 34 percent. Without such savings, Bell System need for nickel in 1952 would amount to 2,872,300 pounds.

The reduced amount needed by the Bell System in 1952, however, reflects much more than current substitution and conservation work. It also reflects many improvements in design and advances in manufacturing techniques made in the last decade for operating or economy reasons. The result is that in 1952, re-

quirements will actually be 241,900 pounds less than were the requirements for 1941, even though Bell System production for 1952 will be over twice as large as in 1941. If the Bell System were still using 1941 designs and processes, about 4,750,000 pounds of nickel would be consumed annually at today's going rates.

Nickel has always been used as sparingly as possible because nickel has always been an expensive metal. Economic considerations are basic in the Bell System policy of supplying the best possible telephone service at the lowest possible cost.

World War II and today

The first big nickel pinch experienced by the Bell System came in 1941–42. Drastic reductions in the use of the metal were made necessary by World War II military needs. Before the end of 1942 substitutions and savings were made which, along with some curtailment of production, reduced Bell System use of nickel by more than half.

This was a remarkable achievement. But, of necessity, many of the substitutions were temporary, emergency methods put into effect quickly and with considerable improvisation. The World War II experience, and many studies made since, indicate that if substitutions are not made wisely, the quality of telephone service may be threatened, to say nothing of maintenance and replacement problems which will crop up later and be most uneconomical and difficult to deal with.

Today's situation is complicated by the fact that the system's longtime effort to reduce consumption of nickel has been unusually successful. The Bell Telephone Laboratories and Western Electric, the system's manufacturing unit, are finding it more and more difficult to discover places where the use of nickel can be safely reduced or eliminated. The fact is that the Bell System is now using proportionately less nickel for new plant than ever before.

SAVE—SUBSTITUTE—SALVAGE

TODAY'S CONSERVATION EFFORTS

Since 1950 the Bell Laboratories and Western Electric have gone over the Bell System plant again and again virtually with a fine-tooth comb. No part of any piece of apparatus, regardless of how insignificant, has been overlooked if nickel is involved. Springs, switches, screws, brackets, terminals, dial number plates, coils, pole pieces—literally hundreds and thousands of items—have been studied painstakingly.

Substitutions, however, cannot be decided upon and put into effect overnight. The process requires the cooperation and skills of a great many Bell System people, rearrangements of manufacturing processes, and equipment redesign.

When substitute materials have been selected or developed and availability determined, they must be engineered into product designs. Trial lots of the product, and sometimes the material itself, must be manufactured and tested and specifications prepared. Manufacturing drawings, methods, and tools have to be revised. Production samples need to be studied, tested and manufacturing difficulties ironed out. Once the products are in service, field performances must be studied. All this has to be done for every item.

In studying the problem of substitutions, the task is approached from the standpoint of how the metal is employed in the telephone system. The use of nickel divides quite naturally into a number of categories. The largest uses of nickel are in magnetic alloys, in nickel silver, in electroplating, and in purchased alloy forms. Of these categories, the Bell System uses more nickel by far in special purpose magnetic alloys than in any other.

MAGNETIC ALLOYS

Estimated savings for 1952—371,000 pounds of nickel

Approximately 60 percent of the nickel the Bell System needs for 1952 will be used in magnetic alloys—a total poundage of nickel amounting to more than 1,100,000 pounds.

Much of it will be used in loading coils, which are placed in circuits to aid transmission. But much more nickel would be required if it weren't for the fact that loading coil cores have been the subject of intense research and study for many years. Starting as long ago as 1941, some loading coils were redesigned to

use only half as much permalloy in their cores as before. In the intervening years improvements have been made steadily in the uses of permalloy. The result has been that in 1951 almost 2½ times as many loading coils were produced per pound of nickel as in 1940.

Of the 371,000 pounds of nickel which will not be used in magnetic alloys in 1952, 276,000 pounds are being saved by the use of silicon steel for permalloy in the cores of some transformers, retardation, and repeating coils and also in the HA–1 receiver pole pieces. Another sizable saving of 89,000 pounds is resulting from the use of magnetic iron for permalloy in 2 types of ringer cores.

NICKEL SILVER

Estimated savings for 1952—474,000 pounds of nickel

Nickel silver—an alloy of copper, nickel, and zinc without any silver in it—is employed throughout the Bell System plant. It is used in thousands of items, principally in contact springs. It would be difficult—if not impossible—to make a telephone call anywhere in the United States without the help of this alloy.

Before World War II, nickel silver containing 18 percent nickel became the standard for many contact springs. It was adopted because it was considerably superior to metals used up to that time. Recommending it were such characteristics as excellent springiness, good contact-welding properties, relatively fair conductivity and resistance to corrosion.

Since 1950, however, 18-percent nickel silver has become virtually an alloy of the past so far as telephony is concerned. Bell System research and engineering succeeded in developing a new alloy containing only 12 percent nickel which can be used for springs of certain relays, switches, jacks, and numerous other items. Thanks to this, nickel in the Bell System is now being saved at an annual rate of 279,700 pounds.

Because of the large savings which have been made through the use of 12-percent alloy for contact springs, the National Production Authority has recommended its use for this purpose throughout the entire communications industry. To make this possible, the manufacturing information developed by Western Electric, both for making the new alloy as well as its application, plus a great deal of Bell Laboratories data concerning this alloy's physical characteristics, all of which is new, has been made available to other manufacturers.

In the cases of a few parts it has been found that nickel silver can be completely abandoned. Brass has been substituted in certain switch and relay springs, in relay screws and the like, to save nickel at an annual rate of 168,300 pounds. Another 16,700 pounds is not being consumed each year because zinc-plated steel has been adapted for certain relay shells, apparatus brackets, and other parts.

NICKEL PLATING

Estimated savings for 1952—13,300 pounds of nickel anodes

Compared to the quantities of nickel used for other purposes in the Bell System, nickel used for plating doesn't amount to very much. Nickel-plating is, nevertheless, very important for functional reasons where problems of resistance to corrosion and wear are involved.

Substitutions already in effect have cut the amount of nickel normally required by the Bell System for plating by about 20 percent. Zinc, chrome, or copper plating is being used in some cases. In others, the nickel finish has been omitted entirely or reduced in thickness. The latter method is saving about 7,500 pounds of nickel anodes in the production of dial number plates. The nickel coating (applied before the ceramic finish) has been reduced in thickness by at least 50 percent.

Investigation of plating as applied to relay cores and armatures has also been one of the engineering studies under consideration. Many years of development work has resulted in perfecting these devices to operate hundreds of millions of times without attention. Substitutions for nickel-plating involve questions of operation and release of the relays, problems of corrosion and wear, and the possibility of sticking of armatures. Nevertheless, Western Electric is realizing an annual saving of 3,400 pounds of nickel anodes by closer control of the thickness of the nickel coating on these parts.

OTHER ALLOYS

Estimated savings for 1952—125,900 pounds of nickel

There are a number of alloys purchased by Western Electric in sheets, strips, and other forms suitable for manufacturing. One of the more important is stainless steel which is employed for parts which must be exposed to corrosive materials, atmospheres, or underground conditions. The strength and stability of these steels make them particularly valuable for apparatus parts and hardware used by the Bell telephone companies.

Nevertheless, Bell System requirements for nickel-bearing stainless steels have been cut by about 70 percent. These results have been achieved, in part, by wide use of chrome stainless steel or ordinary steel, zinc-finished.

In at least one instance, the usage of nickel-bearing stainless steel has been increased to save nickel. This occurred in the instance of a part in the magnetic circuit of the receiver of the new 500-type handset which was originally designed to be made of an alloy containing 76.5 percent nickel. Engineering studies, however, revealed initially that stainless steel containing 25 percent nickel could be used and then later, that stainless steel containing 8 percent nickel might be employed. The potential annual savings in nickel in 1952 by this substitution alone comes to 78,500 pounds.

The success of the Bell System program to date has been due to a willingness to concentrate an unusual amount of research and engineering upon nickel and a willingness to make savings here, there, everywhere in the system, even though some savings may amount to no more than a few hundred pounds. This work has been so thorough that scarcely any opportunities remain for making new savings without seriously impairing telephone plant.

The facts as presented in the preceding pages are merely the highlights of the story of nickel conservation in the Bell System. The complete narrative, with all details and with proper emphasis upon research, engineering, and manufacturing, is too complex to be told in a few pages.

However, this big story is in the records and, in a nutshell, this is the way it reads:

Bell System nickel requirements in 1952 are actually less than in the final prewar year 1941, despite the fact that production of telephone equipment has more than doubled.

STATEMENT OF ROBERT M. BURNS, CHEMICAL COORDINATOR, BELL TELEPHONE LABORATORIES, MURRAY HILL, N. J.

Senator MALONE. Now we have Dr. Burns, of the Bell Telephone Laboratories.

Doctor, I will ask you to kindly identify yourself for the record, and proceed with any statement you care to give that you think may be of interest to the committee.

Mr. BURNS. Thank you, sir.

Senator MALONE. I might say that one of my good friends, with whom I went to school, went up to the Bell Laboratories, and got lost up there in New York someplace. They say he is pretty good.

But you have worked out some very important problems for the United States of America. So will you just proceed in your own way, as you see fit.

Mr. BURNS. Yes, Mr. Chairman.

RESEARCH FOR INCREASED USE OF SUBSTITUTES

I am Robert M. Burns. My present title is chemical coordinator. I was for about 10 years director of chemical and metallurgical research. It is a pleasure to come down and discuss briefly some of the contributions of research toward alleviation of the critical materials situation. I am presenting a prepared statement for the record and I shall, with your permission, amplify some parts of this. First, may I

say that the Bell Telephone System because of its organizational setup is in a fortunate position in being able to make rapid and effective contributions toward economies in the use of critical materials. Long-range research at Bell Telephone Laboratories leads to the discovery of new materials and new technology and reduces the necessity of depending so heavily upon the more critical materials as acute shortages develop. Laboratories engineers working in close collaboration with engineers of the American Telephone & Telegraph Co. and manufacturing engineers of the Western Electric Co. have been able to take steps toward the increased use of substitute materials, at the same time maintaining the high production schedules required in the manufacture of telephone and military equipment. I want to emphasize the fact that the close relationship of the engineers of the three organizations makes this possible. Efforts of this kind, for example, made it possible in 1953 to save nearly 2 million pounds of nickel that otherwise would have been required had the design practices and materials usages of 1941 been necessary in the 1953 production.

The telephone industry is a user rather than a manufacturing industry when it comes to materials. In order to have the necessary basic knowledge of the properties and performance of materials and be intelligent in their use, the Bell System supports long-range materials research. It is an essential part of our business.

Among the many savings in critical materials accomplished through research that are mentioned in my prepared statement is that of antimony commonly used in the lead plates of storage batteries. By using 0.06 percent calcium instead of 8 percent antimony as the hardening agent, we are at present realizing an antimony saving of nearly 200,000 pounds a year and getting a better and longer life battery.

Senator MALONE. Does it make any difference in the production cost?

Mr. BURNS. Yes; calcium is lower in price than antimony, and we use less of it. The manufacturing know-how has cost a little more so far, about 10 percent in the beginning, but we believe that it may be no more expensive in time and perhaps less expensive, because of using less hardening agent and a cheaper hardening agent.

Senator MALONE. By the way, I did not mention the name of my friend at the University of Nevada. His name is Jock Aiken. He is in the laboratory someplace. He is considered to have some brains.

Mr. BURNS. That is what we need.

Senator MALONE. I have often been intended to go look him up.

Mr. BURNS. We would be happy to have you do that.

Senator MALONE. Your testimony is very, very interesting. You have mentioned now two strategic materials.

Mr. BURNS. Yes.

Senator MALONE. It is a very important field.

The chairman has tried to emphasize 2 or 3 times what you have just said, because in the long run, people will get the full significance of it, I am sure.

American people, of course, understand very little about these fields unless they happen to be interested in an industry, unless it is someone that is studying them. When we refer to a substitute or replacement. the natural picture is something of a temporary nature. But there are so many instances, just as you mentioned, that once you discover the

substitute or replacement, you never go back, because it is either cheaper or more efficient, or both.

Mr. BURNS. That is one of the interesting rewards—as you might call it—for doing this. You not only alleviate the situation but you get something in return which is better.

Senator MALONE. More economy.

Mr. BURNS. We could illustrate that in a number of cases.

Senator MALONE. The more you can say that as regards critical materials, the better we like it.

Mr. BURNS. With respect to nickel savings, I might mention the fact that our finding that the nickel content of an alloy known as nickel silver could be reduced from 18 percent to 12 percent without loss of desirable properties led to an annual saving of nearly 300,000 pounds of nickel in the Bell System.

Senator MALONE. Do you find that when you work out these procedures and methods of saving these materials they apply to other industries besides your own?

Mr. BURNS. Yes, in addition to finding that a newly developed substitute is sometimes as good or even better for our own purposes, we have found that other industries are served equally well by the substitute. This is the case in nickel silver.

Senator MALONE. Have you any idea what it might save in the entire industry?

Mr. BURNS. This is difficult to estimate because it is not known how completely producers of nickel silver have converted to the 12 percent alloy in their present production. Following our discovery of this alloy and during the Korean war, the National Production Authority stipulated that no nickel silver spring stock could use more than 12 percent nickel while all other nickel silver could not use more than 10 percent nickel. It is estimated that the total nickel silver consumption for 1954 will be about 20,500,000 pounds. If all of this were the lower nickel alloy (which is unlikely), there would be a prospective saving of nearly a million and a quarter pounds of nickel on this development alone this year.

Turning now to an example of synthetic materials, quartz may be mentioned. Laboratory and pilot plant studies indicate that it should be possible to grow sufficient quantities of this material to meet the needs of the electronic and communications industries.

Senator MALONE. You might describe what the process is without disclosing any secrets.

Mr. BURNS. There are no secrets that we wish to withhold here.

Senator MALONE. Just for the benefit of the record.

Mr. BURNS. The process consists in dissolving sand or fragments of quartz in an alkali solution (water containing sodium hydroxide or ordinary household lye) under high pressure and temperature and crystallizing out on a seed plate of natural quartz held at a slightly lower temperature. To obtain the necessary pressure of about 15,000 pounds per square inch, the nutrient solution and seed plates are enclosed in an inner hermetically sealed tube and this in turn inserted in a heavy walled bomb to withstand the required pressure. The bomb is placed on a heating unit and the bottom part containing the sand or quartz fragmentes heated to 400° C. (750° F.). Crystallization occurs on the seed plates in the upper regions of the tube at about 380°

C. (715° F.). It takes about a month to grow crystals of about a half pound which are the size necessary for commercial use. About 40 such crystals can be grown in a pressure vessel 8 feet in length at one time.

Senator MALONE. It is not very expensive?

Mr. BURNS. No, it looks as if synthetic quartz could compete economically with the natural product.

Senator MALONE. I am glad you put that in the record.

As interested as I have been over the years in our becoming self-sufficient in this area, that is about the best description I have heard.

You have seen our report, have you?

Mr. BURNS. Yes, I have.

Senator MALONE. We would like to have such information about any item in your business. We want it because we have very little basic information on that score in this committee.

But I have taken so much punishment over the years, and I would say we could probably become self-sufficient in the Western Hemisphere if we put our minds to it.

Mr. Burns. I think so.

Senator MALONE. And if we will bend our minds to it, those few things that are still lacking can be accomplished in a very reasonable time.

Mr. BURNS. I have some feeling that if we put ourselves to it and do some research here, we can be successful.

Senator MALONE. Especially when it comes down to your threatened security.

Mr. BURNS. Very much so.

Senator MALONE. You must realize that we have been pushed around for 37 years all over the world, and with the threats over us, if we allow 1 nation, whether it is Germany or Russia, to dominate either Germany or Asia, or any substantial part thereof, we will be next. Because of that, we have to defend these areas across the ocean because they are the source of our material. Ninety-nine and one one-hundredth percent of our population knows no different than that, because they cannot possibly know the difference; they are busy making a living in their own fields. So they are just scared to death.

So I really came to the Senate to do this job; this is my forte.

Mr. BURNS. It is a very laudable purpose.

Senator MALONE. I know every producer and engineer in the United States of America that has done anything or accomplished very much, either by reputation or personally, and I am completing my acquaintanceship as much as I can.

I think you will find that we recommend that the Congress start by making $50 million available to the proper people in the Government to cooperate with companies or in any way they see fit to continue their research. We almost put in $100 million. There was some remark that if the principle is right we can increase it without any trouble.

Mr. BURNS. It is very constructive, I think.

Senator MALONE. One thing I know from being consulting engineer to many companies at different times is that any company that neglects their laboratory work for 5 years is out of business. That happens because somebody else will create something that will take the place of what they are doing, either cheaper or better, or both.

Go ahead.

CORROSION OF METALS

Mr. BURNS. I want to mention now corrosion of metals.

The best estimate that I have seen is that it costs this country about $6 billion a year, if you include the cost of protective measures and the things that you have to do about it. While it is impractical, I think, to save all of this, it is my opinion that, if a greater effort is made here in this field, we could at least make a 10-percent saving. That would be half a billion dollars and thousands of tons of critical materials.

Senator MALONE. Which is probably more important than the dollar value.

Mr. BURNS. I would agree.

My submitted statement makes reference to research on the solid state of matter that led to the invention of the transistor. This device performs many of the functions of the vacuum tube. Besides extending electronic technology, it promises to contribute to miniaturization of apparatus and reduce the volume of materials—some of them critical—that are required to perform a given function. One of the byproducts of transistor research has been the invention of a device called a silicon solar battery, which converts the sun's energy directly into electrical energy. The efficiency of this conversion is now about 8 percent. The device consists of silicon metal containing controlled but very minute concentration of certain impurities. We believe that this 8 percent efficiency can be doubled, but even now this battery or converter is about tenfold more efficient than any other process for converting directly the sun's energy into electrical energy. In practical applications, a storage battery will be employed to store the electrical energy obtained from the solar radiation on the solar battery.

Senator MALONE. Are you talking about solar power?

Mr. BURNS. Yes, solar energy.

Senator MALONE. Is there any limit to the size of this storage battery or amount of energy that you can transmit to it?

Mr. BURNS. We think it would not require a very big storage battery in our own application for furnishing power at remote stations.

Senator MALONE. What I really meant and why I raised the question is this: Is there any limit to the amount of current that could be generated?

Mr. BURNS. No. The larger the area the more you can generate.

Senator MALONE. What is it per square foot, if you know, or——

Mr. BURNS. It is about 80 watts per square yard in full sunlight.

Mr. GARRETT. That could be made tenfold more efficient in the future, is that it?

Mr. BURNS. At the present time it is about eight. That is, 8 percent of the sun's energy that falls on the silicon surface is converted into electrical energy. We think it may be possible to double that, practically.

Senator MALONE. It would reduce the area required for the same amount of power, would it?

Mr. BURNS. Yes.

Senator MALONE. This is more or less a recent discovery, is it not?

Mr. BURNS. Yes.

Senator MALONE. Is this not then a great step ahead in this study of solar power?

Mr. BURNS. We think so.

Senator MALONE. I think there was an article written on it.

Mr. BURNS. It was recently given some publicity.

Senator MALONE. I think the committee would be interested in that particular phase of it.

Mr. BURNS. I will supply as an attachment for the record a description of the Bell solar battery that appeared in Bell Laboratories Record for June 1954.

Senator MALONE. You see, there is another source of power, nuclear power. The Army is already planning on building a working unit on a flatcar so that they can take it out to an Army camp for electrical energy.

And right now, the Government is building a 60,000 kilowatt plant in Pittsburgh. I take credit for promoting it. But I wanted it in Nevada.

Your mention of mountain or desert areas reminded me of it. It costs 2 to 3 cents out there per kilowatt-hour in some places. So I was selling the idea of building a reactor at Eureka, Nev., with four or five thousand kilowatts, and I had it sold. They made 2 or 3 trips out there, and then I oversold it and they built 1 of 60,000 kilowatts, so we did not get it.

But if it is practical in Pittsburgh, it is practical anywhere. It was only a question of pride in getting it in Nevada, and maybe helping this little town. But, really, the main thing I wanted was to see one built, and what I would be interested in is to see one of these solar batteries of some size built. Suppose you do that.

Mr. BURNS. We hope so. We want to try it out first.

Senator MALONE. Has there been any patent on the solar battery?

Mr. BURNS. We have background patents pertaining to the general field and applications for patents of more specific kind for the invention of the solar device.

Senator MALONE. Would you tell us, with your experience and background in research, what you consider future hopes of opening up new fields through research, new materials, and the possibility of further activities due to either decreasing the cost of a process or making substitutions?

The reason why I am asking you that is that every once in a while someone says we are old fashioned and that we know everything there is to be known and there is nothing further to be done but to use up what we have.

Of course, none of us believes that.

Mr. BURNS. My view is that we have a great future before us if we devote ourselves to rather basic research, directed toward getting new facts, new information about materials.

I put that as the No. 1 requirement.

We try to do a certain amount of basic research to discover new knowledge about materials. The transistor and solar battery are good examples of the results. The other thing is that I think it should be possible in this critical materials area to exploit, to go further in processes of benefication, of concentration, of treating low-grade ores. It seems to me reasonable to expect that research devoted to development of better methods, entirely new methods of extraction of metals from their minerals, ought to be in the right direction.

Senator MALONE. In other words, the only difference often is a better method of beneficiation?

Mr. BURNS. That is right.

I am very much sold on the importance of research here. And I can say that, in a general way, as far as we are concerned, as user of materials, and a very large one, we have been able to solve practically all of our scarcity problems by using substitutes. But in many cases, these studies yielded unexpected rewards in the form of new discoveries.

Senator MALONE. Then your results as to solar power, splitting of the atom, resulting in possibly nuclear power, it seems that that opens an entirely new and unexplored field.

Senator MALONE. We will have to recess now, as I must go to the floor.

Mr. BURNS. I am through. That is all I intended to say.

Senator MALONE. We appreciate very much your appearance here today, sir. Perhaps you have a little better understanding now of what the committee is trying to do.

Mr. BURNS. Yes.

Senator MALONE. Your testimony will be submitted to you for corrections or additions.

Mr. BURNS. Shall I amplify it?

Senator MALONE. Amplify any subject that you think will be helpful to the committee.

We are particularly interested in critical materials, in making them more available and at lower cost, or in any manner assisting us to become more self-sufficient in the Western Hemisphere. And, of course, the more we improve our own production economically, the greater security we will have, in my humble opinion.

So you can see that the Senate is very much interested in the subject and will be more interested in it if they see what has been accomplished.

Mr. BURNS. Yes, Senator.

Senator MALONE. We will recess at this time until 2:30, to hear Mr. Jackson.

(Whereupon, at 12:45 p. m., a recess was taken until 2:30 p. m., this same day.)

AFTER RECESS

(The subcommittee reconvened at 5:45 p. m., upon the expiration of the recess.)

Senator MALONE. The subcommittee will be in order.

We have with us Mr. J. M. Jackson, manager of the research laboratory, American Can Co., of Maywood, Ill.

Mr. Jackson, if you will identify yourself for the record and make any statement you think will be helpful.

You have listened to some of the hearings and you are no doubt familiar with the basic reports, so you know the objectives of the subcommittee.

You are familiar with Resolution 271 of the Senate, 1954?

STATEMENT OF J. M. JACKSON, MANAGER, RESEARCH LABORATORY, RESEARCH AND TECHNICAL DEPARTMENT, AMERICAN CAN CO., MAYWOOD, ILL.

Mr. JACKSON. Yes, in a general way.

Senator MALONE. It is information we are looking for and we think you may have something very interesting for us. Go right ahead.

Mr. JACKSON. I am John M. Jackson, manager of the research division laboratory, American Can Co. I have a Ph. D. in chemistry from the University of Chicago and have been employed by the company since 1932. In my present capacity, I report to the director of research and he in turn reports to the general manager of the research and technical department.

Our company is in the business of manufacturing metal containers, popularly known as tin cans. The tin can is widely distributed and is a single service disposable item which is often the butt of many jokes. People often refer to inferior objects as "tinny" but in spite of that the tin can has taken a very important place in the civilian economy during the last 50 years.

Senator MALONE. There are a lot of different kinds of tin cans, are there not?

Mr. JACKSON. Yes; there are very many.

The can is very important for the preservation and distribution of perishable foods and also for distribution of numerous household and industrial products. The industry has grown very rapidly. The total can manufacture in this country in 1900 is estimated at about 2 billion containers. In 1953, there were over 35 billion containers manufactured.

The tin can and the canning industry make substantial contributions to national health through improved diet, they are of assistance to agriculture, by permitting the marketing of perishable products which may be grown in rural, sparsely populated areas, and later sold in the heavily populated areas.

The industry has given considerable assistance to the farmers through advice on growing canning crops and employment at the canneries helps to stabilize the economy of many small towns throughout the country. Furthermore, it is well known that the tin can is a military necessity, both for feeding the Armed Forces and for distributing various other supplies, such as medical supplies, to the Armed Forces.

In 1951, discussing the importance of cans and the canning industry, the Quartermaster General stated that cans are required to feed the troops when refrigerated shipping and storage are not available. In other words, as he said, "The dollar goes into the can."

Some nonmetallic substitute containers were tried during World War II, and they left the Quartermaster with the realization that "no other container protects like the tin can," because of failure of substitute containers under severe storage conditions.

Now just a word as to the structure of the can. The so-called tin can is made from tinplate which is steel plate carrying a very thin coating of tin, which may vary from approximately one-quarter of a percent of the weight of steel up to about 1½ percent of the weight of steel.

Senator MALONE. That was quite an innovation in the saving of tin supply, was it not?

Mr. JACKSON. Yes, much has been done in reducing the amount of tin per ton of steel.

Based on the annual consumption in 1953, the raw materials used to make this 35 billion cans were approximately 4 million tons of steel and 23,000 long tons of tin. A few million pounds of rubber are used in the sealing compound which seals the end seams. Prior to World War II, of course, natural rubber was used.

Senator MALONE. How many pounds of steel?

Mr. JACKSON. About 4 million tons of steel which was about 5 percent of the total United States steel production.

Use of synthetic rubber has been adapted for the end sealing compound and it does a better job than the natural rubber.

Senator MALONE. Did I understand you to say that synthetic rubber can be manufactured and does a better job than the natural?

Mr. JACKSON. It does a better job for sealing the can end seams because it can be tailored for the particular purpose. Some materials require fat resistance and others require resistance to heat and moisture.

Senator MALONE. Manufactured specifically for the purpose to be used?

Mr. JACKSON. Yes, rubbers which are manufactured for that use.

Senator MALONE. For a long time there was a place where natural rubber would do a job better. We have practically overcome every obstacle to where synthetic will do as well or better?

Mr. JACKSON. I think that is true.

Senator MALONE. It is a shining example of what scientists can do if they have to.

Mr. JACKSON. Enamels, or protective coatings, are used both inside and outside the can both for protection and to decorate the can. The coatings are made up of various resins and drying oils. These also used to be imported materials, but domestically available materials are now satisfactory and readily available. That usage amounts to an estimated 80 million pounds a year.

Senator MALONE. Let me ask you at that point and perhaps you cover it further along in your statement. Is there any other metal that can be made to take the place of tin in an emergency or a substance to replace it to any extent?

Mr. JACKSON. We do not believe that any single metal will replace tin because of its unique properties. We feel that for some types of containers we may be able to use one type of metal on steel and for others another type of metal or organic coating.

Senator MALONE. Because of the material inside the can?

Mr. JACKSON. Yes.

Senator MALONE. I have in mind particularly, someone mentioned it during the course of the 58 hearings that we had before we published our report, someone mentioned titanium as being a possible substitute in the future under certain conditions.

Mr. JACKSON. We feel it would do a very good job. The cost certainly looks prohibitive now, but we do not know what might happen in the future.

Senator MALONE. Is it a satisfactory substitute if costs were right?

Mr. JACKSON. It certainly would be satisfactory for some products. It has very high corrosion resistance, so that it might be used, if it could be coated on steel. It might be possible to use steel coated with

titanium to hold a number of acid products, and other corrosive products.

Senator MALONE. You would not have any idea as to what percentage of the tin now consumed could be replaced if the price should come down within range, do you?

Mr. JACKSON. I would guess it would be quite a large percentage that could be replaced with titanium.

Senator MALONE. It could be almost a complete replacement if the economic conditions were not a controlling factor and you had it available?

Mr. JACKSON. Yes, provided that we would get an impervious coverage of the steel base with the titanium.

Senator MALONE. You are not sure that that can be done?

Mr. JACKSON. No. Any porosity in the titanium coating might permit corrosion of the steel from underneath the titanium.

Senator MALONE. That would be a problem.

Mr. JACKSON. So far it looks that way; that might depend on the thickness of the coating of titanium.

Senator MALONE. Is it on account of the brittleness of the coating when it is applied?

Mr. JACKSON. Presumably such a coating on steel would be very thin and porous.

Tin coating is also porous, but it so happens that within a can the electrochemical relationship is such that tin protects the steel from corrosion so that even though some of the steel base may be exposed, as long as there is tin in the can the steel is protected and the corrosion is retarded.

Senator MALONE. Thank you. Go ahead.

AVAILABILITY OF TIN

Mr. JACKSON. Of the various materials that I mentioned, tin is really the critical raw material because it is not available within the continental United States in any significant quantities, apparently it is not available in the North American Continent in any commercial quantity.

Senator MALONE. I want to digress at that point, not to interrupt your line of thought, that our report shows that while it is not available in the North American Continent, at this time at least, it is available in the Western Hemisphere but at this time a very considerable part of Bolivian tin in that area, the best grade of the tin is shipped to Europe, to England, to be exact, processed there, and we purchase a large amount. Thus it is shipped across the ocean twice, which seems to be a useless thing, and the Bolivians do not like it.

The only smelter in this country, in Texas, has a maximum capacity of 40,000 tons which happens to be just about the amount you could do with in an all-out war which would be about 20,000 tons less than they usually use in peacetime. That is all explained in the hearing. It just happens that you could step that production up to pretty close to 40,000 tons annually in South America, according to the testimony. So if we have just gumption enough not to wreck our own setup, perhaps in the comparatively near future, at least the foreseeable future, there may be a little commonsense enter into the handling of it. Of course, there has been evidence of no commonsense entering

into the handling of any commody, but I believe that Congress is about to take a hand in that.

I just mention that to round up your statement that it was not available to any great extent in this hemisphere.

Mr. JACKSON. That is certainly very important. I hope that some action of that kind will be taken.

Senator MALONE. I think it will.

Mr. JACKSON. As you know, just to complete the record, about 54 percent of the total world production of tin comes from over in the southeast Asian area, the Malay Peninsula, and Indonesia.

Senator MALONE. And, as a matter of fact, to complete the record again, while the top-grade tin goes from the Western Hemisphere to England or Europe, we are dependent, as you just said, on Indonesia and the Malayan States for a large amount of our tin. It just does not make any sense because you could not ship it across the ocean in the event of a war, and it is an added expense anyway, making two trips across. But there are various ways of making us dependent on foreign soil for things we cannot fight without. So we are in a kind of gentlemanly blackmail, although it is not very gentlemanly at times to enter into further agreements by virtue of becoming dependent on foreign areas so that it might be continued. Half our manganese comes from India, half our annual supply, 900,000 tons. You could not get a ton if war starts. They did stop shipping that once even during peacetime. Reading other reports like the Paley report and the national resources report and the Bell report and others, has not helped. I think we have a reasonable chance of supplanting some of those reports if we can just get men like you to take the time and others that you have heard to help us build up a record of the truth.

Mr. JACKSON. Our company, under the aggressive leadership of our president, is very much concerned about the tin situation.

Senator MALONE. Who is your president?

Mr. JACKSON. William C. Stolk. He has been pushing a program in our company to get away from the dependency on tin. This project has been called Operation Survival.

Senator MALONE. Give him our best regards, and tell him we appreciate his help.

Mr. JACKSON. I certainly will.

Senator MALONE. Is the head office in Illinois?

Mr. JACKSON. The head office is in New York City.

Senator MALONE. Is that where your president lives?

Mr. JACKSON. Yes, sir.

SUPERIOR PROPERTIES OF TIN

To return to tin, for a moment, its unique properties make it very difficult to replace. In the first place, it has an attractive appearance. It is self-lubricating so that passage through the equipment is facilitated during the fabrication of the cans. One of the most important considerations is that it is safe for contact with food products. it is nontoxic. Incidentally, the idea that so many housewives have had that food should not be left in an opened can, is entirely erroneous; we do not know where that myth originated.

Senator MALONE. Was that true a long time ago?

Mr. JACKSON. Not as far as we know. That was a generally held idea a few decades ago, but we cannot understand what the basis was

for such thinking. It is true that once the can is opened it must be refrigerated or it is subject to bacterial spoilage.

Senator MALONE. I am older than you are and I can remember 50 years ago, it stands out clearly in my mind, that the danger of contamination, once it was opened, was well established, whether it was based on any facts or hallucinations, I do not know.

Mr. ADLERMAN. I know, my father was a doctor, and he always insisted the moment the can was opened it must be used.

Mr. JACKSON. We have a statement that we quote from one of the Department of Agriculture publications which points out that it is perfectly safe to leave food in the open can if it is refrigerated.

Senator MALONE. I just assumed that there was an improvement along the line that I had missed somewhere that corrected that tendency. Go ahead.

Mr. JACKSON. Another of the properties of tin is that tin in itself is corrosion-resistant and, as I mentioned before, on the inside of a can in the absence of oxygen it protects the steel from corrosion even though there may be pores in the tin coating. Under outdoor atmospheric conditions, the reverse is true, the steel rusts underneath the tin, and that is why cans that are left around in a dump rust and disintegrate rather quickly.

CONSERVATION OF TIN

Prior to and during World War II, a program for tin conservation was undertaken which depended, in part, on the application of tin to the steel by electroplating rather than the hot dipping, similar to the electroplating procedure that Dr. Burns mentioned in connection with the tinning of wire this morning. That permitted a considerable reduction in the amount of tin used per ton of steel which enabled us to have cans available for civilian use in addition to the military use during World War II.

Senator MALONE. That electroplating can also be regulated for thickness?

Mr. JACKSON. That is right.

Senator MALONE. Much more efficiently, can it not?

Mr. JACKSON. Yes.

Senator MALONE. That is a deposition and can be pretty thoroughly controlled?

Mr. JACKSON. Yes. Much of the electrolytic tinplate has one quarter of a pound of tin per base box of tinplate, whereas the hot-dipped tinplate has a pound and a quarter per base box. A base box is a unit of area.

Senator MALONE. What area would that be?

Mr. JACKSON. About 31,000 square inches.

Senator MALONE. 144 square inches to the foot. How many square feet is that?

Mr. JACKSON. Approximately 218 square feet.

Through the use of the electrolytic process, the use of organic enamels in combination with the tin coating and improvement of the corrosion resistance of the base steel, the use of tin has been reduced so that in 1952 the pounds of tin per ton of steel were somewhat less than half of the ratio used during 1941. The cumulative dollar saving over that period has amounted to something over $500 million worth of tin

However, although we think that saving is certainly significant, we do not feel that it is sufficient because we are still largely dependent on tin for manufacture of cans for many products.

Referring to the President's Materials Policy Commission report of 1952, the known world sources of tin were equivalent to about 25 to 30 times the present annual consumption. What the actual resources may be, beyond the known resources, of course, is anybody's guess.

Senator MALONE. It sounds like Harry Dexter White. He said in 1945 that we would be out of petroleum in 13 years and out of tungsten in 3, and he sold it to the Secretary of the Treasury Morgenthau, who in turn sold it to the President, who in turn sold it to the country, and scared them half to death.

Now you have several times that much; that is the history of raw materials.

Mr. JACKSON. That is very true, and it is very likely that more tin will be discovered, but finding ways to protect ourselves against the ultimate depletion of tin appears to be worth while.

Senator MALONE. Conservation such as you are practicing in making it go further for the same amount is a wonderful thing, but I would say to you that I do not think the area around Bolivia and Peru has been thoroughly explored.

Mr. JACKSON. I would think that is very likely true.

Senator MALONE. That is one reason we are taking a trip down there to see.

Mr. JACKSON. Of course, there are a lot of political factors to consider in the world situation. Even though the tin might be available, there is a question of whether it will be available to us.

Senator MALONE. Tin will be available to us in the Western Hemisphere, but it will not be available to us any place else once war starts.

Mr. JACKSON. We are working in this Operation Survival project, attempting to eliminate tin altogether from metal containers for certain products. It will be easier to do for some products than others. The best example that we have in commercial production is a motor oil container made with enameled steelplate. The side seam is closed with an organic cement so that there is no solder and no tin in the can as a whole. One of the most obvious replacements for tin, then, is the enamel coating on steel.

We also are considering other metal coatings on steel. Aluminum coating on steel would be good for many products. We have estimated that possibly 35 percent of the present canned products could be held in aluminum or aluminum-coated steel.

Senator MALONE. How is aluminum applied?

Mr. JACKSON. That is the big problem at present. Research is being conducted on three methods of application. One is hot dipping, one is electroplating, and the third is called a cladding process, in which an aluminum foil is rolled on to the steel with heat and pressure. None of those methods have been entirely successful as yet. In fabricating the cans the metal is drawn or bent at a sharp angle, and if there is any loss of adhesion between the coating and the base steel a failure occurs in the can fabrication.

Nickel would also be a good alternate if it were readily available. Of course, we know it is available in this hemisphere, but it certainly has always been on the critical list. I do not know whether that situation might change at some time or not.

Senator MALONE. I think it will change, and it is changing rapidly. Cuba is a great potential producer, we think, but it is a complex ore, and they are putting a great amount of effort into it now, and they think it is in sight in the foreseeable future.

Mr. JACKSON. That is very encouraging.

I have already mentioned that titanium would be a good alternate for tin if it became available at an economically feasible rate.

Senator MALONE. Most of the experts think there is going to be a substantial drop in price in the foreseeable future and if they could reach the shortcut that would dodge the sponge, the metal might not cost more than the sponge does now. However, even at that price for this strength-weight ratio, it is in great demand. One other thing that recommends it, at least to the chairman of the committee, the raw material from which it is manufactured is about the fourth or fifth most plentiful material on the earth's surface. In many parts of the United States and southern Canada it looks as though there is enough in the country to last a thousand years, at least the potential development. So it is right under our noses and if the price does come down it would replace almost anything. The heat-resistant qualities, too, are great. The report covers that rather thoroughly and I forget the number of the printed hearings, but whatever it is, it is in great detail.

Mr. JACKSON. We have talked from time to time with some of the producers of titanium to try to keep up to date on the progress, and we have had a few samples about as big as a postage stamp to make some experiments with, but no really significant quantities yet.

Senator MALONE. I think it is only a matter of time.

Mr. JACKSON. The only nonferrous metal that we have under consideration for complete replacement of tin and steel is aluminum alloy sheet, which might be satisfactory for metal containers for a number of products. There, again, we have a question of coat in the final fabricated sheet, questions of strength and corrosion resistance for some products. It is good for some products and not good for others.

Senator MALONE. Did I understand you to say that under certain conditions where cost was not a factor that you could probably do without tin in the foreseeable future for a considerable length of time?

Mr. JACKSON. Yes, I think we could for the noncorrosive type of products.

Senator MALONE. And if any such metal as titanium would become available, that would answer that question, would it not?

Mr. JACKSON. Yes, it would.

Senator MALONE. And in wartime, of course, cost is not the controlling factor if you really had to have a certain product and it could be made available at all?

Mr. JACKSON. Yes; however, the big problem, as we see it, is that it is difficult to make a conversion rapidly. What we hope to do is to be able to make these conversions gradually under peacetime conditions which means that we have to develop alternate containers which will be competitive with tin cans on the basis of performance, appearance, and cost; that is a pretty tough problem, but that is the one that we are working on.

In the case of motor oil cans, we have achieved it. We hope to achieve it in other cans.

Senator MALONE. I think it is a very important work.

Mr. JACKSON. In addition to the materials one of the big problems is the sealing of the side seam. Tinplate is easily soldered. These alternate materials are more difficult to solder. We are working on developing some special soldering methods. We are studying the possibility of electric welding of the side seam, and we are working on the use of organic adhesives or cements for closing the side seam. We are using one successfully on the motor oil can. For heat-processed foods, we would need a much stronger bond. We have found some cement materials that are much more promising, give much greater bond strength, but there is much work to be done yet to develop them to successful performance.

The other line of research is on the development of improved organic coatings, the use of chemical treatment, such as the bonderizing treatment of steel base before applying the coating and the development of special enamels which may give more corrosion resistance when applied to the steel.

A number of our material suppliers are cooperating in this program. As far as we know, our competitors are doing considerably less work on this type of program than we are.

Senator MALONE. How many companies of substantial capacity are there in the business?

Mr. JACKSON. There are about half a dozen pretty good sized ones.

Senator MALONE. Would you list them for us with some comparison of size?

Mr. JACKSON. American and Continental are the two largest, I think. They have a large portion of the total business. Others are National Can, Crown Can, Pacific Can, and Heekin Can.

Senator MALONE. Will you list their address and some comparison as to production?

Mr. JACKSON. Continental Can headquarters are in New York. Their total volume is close to ours.

Senator MALONE. You are the greatest?

Mr. JACKSON. American is the largest and Continental is second. Continental's total business, including flexible packages, fiber drums, etc., was slightly ahead of American's for the first quarter of this year; in the second quarter American was ahead, so it is very close.

National Can headquarters are in Chicago; Crown Can, Philadelphia; Pacific Can, San Francisco; Heekin Can, Cincinnati.

Senator MALONE. What part of your capacity is export?

Mr. JACKSON. We have very little export business. We have plants in Canada and we export a little to Puerto Rico, to the Philippine Islands and possibly to some of the South American countries. We have a subsidiary in Venezuela in which we have less than a controlling interest.

Senator MALONE. They manufacture the can?

Mr. JACKSON. Yes.

Senator MALONE. Get the raw material right there in South America?

Mr. JACKSON. No. The tinplate is exported from the United States to Venezuela. Some of the plate is enameled and lithographed in the States.

Senator MALONE. Go right ahead.

Mr. JACKSON. I believe that about completes my story. If you have some questions, I would certainly be glad to answer them.

Senator MALONE. I do not believe I have any questions. I think you have made a good witness, approached the question intelligently and thoroughly.

Your testimony will be returned to you to correct and complete because what we need is complete information and you will have plenty of time to correct it.

Knowing as you do now something of the work of the committee, if you consult with your president, maybe he will have ideas that we could further pursue in acquiring more definite information of value to the Congress. We certainly would like his advice, your advice.

I want to thank you very much for coming over and I only regret that we inconvenienced you to a considerable extent, but you see how our business works here.

Mr. JACKSON. Yes.

Thank you very much. I want to thank you for this appearance.

Senator MALONE. I will accept this material, "Research for the Replacement of Tin in the Manufacture of Metal Cans, American Can Co.," as exhibit No. 1 in your testimony for the benefit of the committee.

(The document referred to was marked "Exhibit No. 1" and filed for the information of the committee.)

Senator MALONE. Thank you again, and we will look forward to receiving your corrected testimony.

Mr. JACKSON. Thank you very much.

(The following information was subsequently received for the record.)

UNITED STATES STEEL CORP.,
Pittsburgh, Pa., September 24, 1954.

GEORGE B. HOLDERER,
Staff Engineer, Committee on Interior and Insular Affairs,
Senate Office Building, Washington, D. C.

DEAR MR. HOLDERER: In accordance with my letter of September 17, 1954, there is enclosed a statement prepared by my associates discussing the conservation of alloying elements in stainless and constructional alloy steels. I hope that the statement will be of help to the committee.

Sincerely yours,

E. C. BAIN.

THE CONSERVATION OF ALLOYING ELEMENTS IN STAINLESS AND CONSTRUCTURAL ALLOY STEELS

The tremendously increased aggregate use of alloy steels, particularly for military applications, throughout World War II and the recent Korean episode has led to an awareness of an increasing demand for the alloying elements most commonly used in these steels: nickel, chromium, molybdenum, and, perhaps, to a lesser extent, manganese. The amount of these elements that may be required is, in large measure, a matter of the quantities required in all aspects of the military program, which information is, quite properly, not generally available. These same alloying elements are used in the stainless and heat-resistant alloys for jet aircraft, and stringent conservation measures have been desirable at times to permit the available supply of these critical materials to be spread over the wide range of important applications on the basis of maximum overall utility. These conservation measures, mainly in the form of substitution practices hereinafter described, have been very effective, and although, during the war periods, allocation of these critical alloys to highly essential uses was necessary, the production of ordnance has not, so far as is known to us, been seriously interrupted by a lack of nickel, chromium, molybdenum or manganese.

CONSERVATION IN THE CONSTRUCTIONAL ALLOY STEELS

The principal factor which has made this conservation possible and permitted the uninterrupted production of constructional alloy steels to meet the needs of war, defense, and the ordinary civilian economy, has been the realization of the tremendous significance of a metallurgical principle which is designated as "the hardenability concept." This concept is based on the premise that the properties of steel are primarily dependent on its microstructure and that the microstructure is in turn dependent on the hardenability of the steel. The principal function of the alloying elements is, in terms of this concept, to enhance the hardenability of steel, or in other words, to increase the range of sizes over which desirable microstructures can be obtained by heat treatment. Most of the alloying elements increase hardenability (although in various degrees) and they are therefore, to a considerable extent, interchangeable. Furthermore, and most importantly, combinations of relatively small percentages of several alloying elements are more effective in increasing hardenability than a large percentage of a single element.

With this concept as a basis, the first conservation measure, which was adopted early in World War II, was the development of the so-called national emergency (NE) steels in which relatively small percentages of the three elements, nickel, chromium, and molybdenum, are used in cooperation with the manganese, to impart the requisite hardenability. In some of these steels the manganese content was increased somewhat in order to take advantage of the notable hardenability effect of this widely used alloying element. Although this was a war measure, it was soundly based on scientific fact, and the favorable experience of the users and fabricators of these NE steels has led to their continued use.

The next conservation measure, which was applied to a limited extent during World War II and much more extensively during the recent Korean episode was the use of the boron steels. This measure represents a further application of the hardenability concept and was made possible by the finding that one to three thousandths of a percent of boron exerts a very large hardenability effect and can therefore be used to replace relatively large percentages of the more critical alloying elements. Since boron itself is abundant, and since its availability is limited only by the production facilities for the ferroalloys used to introduce this element into the steel, the use of these boron steels freed very large quantities of nickel, molybdenum, and chromium for other essential uses.

The boron steels were used in World War II for armor, armor-piercing projectiles, and torsion springs for tanks. As an example of the nickle conservation made possible by the use of boron steels, the steels used in the armor of all the tanks used in the latter part of the war and in the Korean episode, contained, we understand, no nickel at all.

The Korean incident brought about further restrictions in the use of the alloying elements in the United States and the use of the boron steels was effective in meeting these limitations. Still leaner alloy steels, using boron to the fullest extent possible, were then developed by a joint effort of the American Iron and Steel Institute and the Society of Automotive Engineers. Each boron steel was designed to replace a conventional alloy steel on an equal hardenability basis. The following table presents typical examples of the savings made possible by this replacement of standard steels by lower alloy boron steels.

Steel designation	Carbon	Manganese	Nickel	Chromium	Molybdenum	Boron	Nickel savings, pounds per ton	Molybdenum savings, pounds per ton	Chromium savings, pounds per ton
4620	0.17	0.55	1.83	.....	0.25	.....	.....	.....	.....
94B17	.17	.85	.45	0.40	.12	0.001	27.6	2.6	.....
8620	.20	.80	.55	.50	.20	.....	.....	.....	.....
80B20	.20	.75	.30	.25	.12	.001	5.0	1.6	5.0
8650	.50	.85	.55	.50	.20	.....	.....	.....	.....
50B50	.50	.85	.....	.50	.....	.001	11.0	4.0	.....
4340	.40	.75	1.75	.80	.25	.....	.....	.....	.....
98B40	.40	.80	.85	.80	.20	.001	18.0	1.0	.....

The savings in nickel made possible by the use of these lower alloy boron steels amounted in 1951 to 12 million pounds. This substantial amount of nickel was thereby made available for those applications in which nickel, by virtue of some

of its special characteristics other than a contribution to hardenability of steel, does not have any known wholly satisfactory substitute.

CONSERVATION IN THE STAINLESS STEEL

In the stainless steel field, as in the case of constructional alloy steels, nickel had been generously and widely used well into the period of World War II, and here it was probably regarded as even more nearly irreplaceable. Columbium (sometimes called niobium) also, was used freely. Chromium, however, was the absolutely essential element in stainless steel.

During World War II, the difficulties of rapid expansion, together with the phenomenal material demands of the armed services, created a scarcity of the alloying elements used in the stainless steels. In particular, the supply of columbium and of nickel was most carefully distributed for maximum utility. To minimize a recurrence of this scarcity, considerable metallurgical research by Government and of private industry during the last 10 years has been devoted to the development of substitutes both for columbium and for nickel. The results of this activity have been so successful that columbium is no longer necessary and indispensable for a very considerable part of the stainless steel applications. Even nickel has been replaced, wholly or in considerable part, in many applications of stainless steel, but chromium still remains absolutely essential.

In the development of substitutes for columbium, attention was given to the two effects of columbium upon the properties of stainless steels: (1) that of improving resistance to intergranular corrosion and (2) that of enhancing elevated-temperature strength. For those applications requiring resistance to intergranular corrosion, the low carbon (0.03 percent C maximum) austenitic stainless steels have been found, by laboratory tests as well as by service trials, to be often as suitable, and in some respects even better than the steels containing columbium. Many chemical companies have completely changed from the use of columbium-bearing stainless steels to the use of the low-carbon stainless steels.

For those applications requiring strength at elevated temperatures, both tantalum and titanium have been found to be satisfactorily effective, if not complete, substitutes for all or a considerable part of the columbium. In steam power, petroleum refining, and jet aircraft applications the titanium-bearing stainless steels and the tantalum-columbium-bearing stainless steels have been successfully used for equipment formerly requiring the columbium-bearing stainless steels.

While the effect of nickel in stainless steel is often regarded as being largely that of forming and retaining an austenitic (nonmagnetic) structure, nickel also significantly improves corrosion resistance. With regard only to forming and retaining an austenitic structure, manganese and nitrogen have been found to be effective substitutes for all or part of the nickel in the chromium-nickel (austenitic) stainless steels. Steels containing 17 percent chromium—4 percent nickel—6 percent manganese and 0.15 percent nitrogen are successfully being used as substitutes for steels containing 17 to 18 percent chromium and 7 to 9 percent nickel. These so-called 17–4–6 steels have a completely austenitic structure and a corrosion resistance approaching (though certainly not equal to) that of the chromium-nickel steels. Further replacement of nickel is possible by increasing the manganese and nitrogen and decreasing the chromium, and steels containing approximately 15.5 percent chromium—1 percent nickel—15 percent manganese and 0.25 percent nitrogen have been used to a limited extent in railway passenger cars and truck trailers. Although the structure of these steels (inaccurately named 16–1–17) is chiefly austenitic, their corrosion resistance is still lower than that of 17–4–6. By increasing the nitrogen content, the chromium content can be increased and trial heats containing 18 percent chromium—15 percent manganese and 0.40 percent nitrogen have been successfully melted and rolled in commercial quantities. These high-nitrogen steels are so new that as yet they have not been evaluated. However, they have an austenitic structure and are, thus far, found to possess excellent room-temperature strength and ductility. If their corrosion resistance should be found to be satisfactory, they would replace much chromium-nickel stainless steel in the transportation industry, and could be used for many other applications in the chemical, food-processing, petroleum-refining, and jet-aircraft industries. However, the results of laboratory corrosion tests indicate that for critical applications in many wet chemicals, manganese and nitrogen are not effective substitutes for nickel in enhancing corrosion resistance. Therefore, for the exacting applications, the use of the chromium-nickel austenitic steels will very probably have to continue so far as stainless steel is applicable.

In summary, the urgent need for most of the columbium in stainless steels is completely eliminated by the development of the low-carbon stainless steels and by the increased use of tantalum- and titanium-bearing stainless steels. The need for nickel in stainless steel merely for the sake of its effect of producing and retaining the desirable austenitic microstructure also may be eliminated by the use of manganese and nitrogen. However, because these elements do not enhance corrosion resistance to the same degree as does nickel, some nickel-bearing austenitic stainless steels will continue to be required.

Synthesis of High-Pressure Minerals

For several years the Norton Co. has been engaged in the study of chemical reactions carried out at very high pressure, the purpose of this work being to discover new substances useful as abrasives.

Techniques were developed for carrying out reactions at pressures up to 45,000 atmospheres and temperatures to 1,000° C. in closed systems.

In the course of this work, a new, harder, denser form of silica was discovered (Science, vol. 118 (1953), pp. 131–132).

Reactions have also been found by which most of the naturally occurring high-pressure minerals can be synthesized under these conditions. The minerals synthesized include the garnets, the epidote group, the high-pressure pyroxenes—jadeite and omphacite, kyanite, sillimanite, and alusite—tourmaline, staurolite, and others of lesser importance.

The conditions found necessary for the formation of these minerals gives considerable information as to the conditions under which natural diamond was formed. The pyrope garnet and omphacite are always closely associated with diamond in nature and apparently crystallized at the same time.

The accumulated evidence indicates that diamond crystallized at a pressure between 30,000 and 35,000 atmospheres at a temperature of 1,000° C. or more.

L. Coes, Jr.

Massachusetts Institute of Technology,
Department of Metallurgy,
Cambridge, Mass., November 5, 1954.

Hon. George W. Malone,
Chairman, Minerals, Materials, and Fuels Economic Subcommittee,
Senate Office Building, Washington, D. C.

My Dear Senator Malone: When Mr. George B. Holderer, staff engineer for the Minerals, Materials, and Fuels Economic Subcommittee, invited me on your behalf to prepare a statement for the records of the committee I was pleased to have this opportunity to serve what I truly believe to be the interests of our country on a long-range basis within the field of the supply of minerals and metals.

While I am not one of those alarmists who are prone to view with distress the utilization and consumption of our mineral raw materials, it is nevertheless patent to any technical man in the field that we have already "taken the cream off the jug" and are reaching further all the time into the milk in layers containing less and less cream.

The processes which on a national scale result in exhaustion of mineral resources are relatively slow developments, with the consequence that the extent of change is not great within the span of a man's life. History teaches, however, that, when the status of a country changes from that of a supplier of raw materials to that of a net consumer, it is well nigh impossible to reverse the trend and bring the country back to the status of a surplus producer. The best that can be hoped for is to bring to a halt the rate of deterioration. The United States is presently passing from the status of an exporting country to that of an importing country in regard to minerals and metals, and the time has come when action must be taken to avoid regrettable if not disastrous conditions a generation or two from now. The fact that many of us will not be here then does not minimize our present responsibility.

At the Fourth MIT Regional Conference which was held in Detroit on January 30, 1954, I had occasion to address the conference on the subject of A Mineral Resources Policy for the United States and at that meeting I had the pleasure of finding myself in complete accord with a fellow engineer, Dr. Robert

E. Wilson, chairman of the board, the Standard Oil Company of Indiana, who spoke on a related topic. The position which I took was that a four-point policy suggests itself:

1. Develop improved mineral prospecting methods and provide financial incentives to stimulate their application. This would find ore.

2. Develop improved processing methods by mineral research. This would make ore out of what is now submarginal material.

3. Study the recycling of metals and minerals in our industrial and domestic scrap heaps in cooperation with municipalities. This would waste less of the material now in inventory.

4. Protect American capital and know-how engaged in foreign lands from confiscation without fair compensation. This would promote world development of mineral and metal resources.

The first step requires the invention of new methods of scientific prospecting. It is one thing to stumble over an ore body that sticks out of the earth and another thing to find a buried treasure. The latter, curiously, is technologically not unlike the problem of locating submarines prowling in the ocean off our shores. In some respects it is in fact a more difficult problem since no two ore bodies are alike in size or physical or chemical attributes while submarines are reasonably alike one to another. Effort is needed in the development of methods for finding covered ore bodies, and later in application of these methods to mineral exploration. The application of scientific prospecting methods might well be left to private enterprise but the development of the methods is of such general applicability and so large an undertaking as to justify Government participation although preferably not on an exclusive basis.

The importance of this need for developing new scientific prospecting methods was the object of conferences held at the Massachusetts Institute of Technology several years ago. In connection with this subject, our vice president and provost, Dr. Julius Stratton, wrote me as follows under the date of February 12, 1952 (quoted by permission):

"I have experienced a growing conviction that the development of better methods of exploring our mineral resources has become one of the foremost technological problems and one that MIT must not neglect. I agree completely with your view that a failure to discover new resources at an accelerated rate may have disastrous consequences on our present standards of living and most certainly will compel changes in foreign policy.

"I also comprehend from personal experience the enormous complexities of the problem. A number of years ago I gave considerable attention to problems of geophysical prospecting by means of electronic devices and am well aware that there are no simple answers. Nevertheless I feel that there is a challenge in this field that we ought to meet here at MIT and I should like to encourage research at the institute along these lines."

The second need, that of developing improved processing methods by mineral research, is one that has shown encouraging signs of growth, particularly because of the interest of the United States Atomic Energy Commission in uranium reserves. The Bureau of Mines also has for many years been interested in improving methods of mineral processing. I would strongly urge that the effort be increased in scope, variety, and intensity and more particularly, that it be so applied as to make a career in the mineral engineering field more attractive to young Americans than it now seems to be. During the past half-century the number of operating units in the American mineral industry has decreased, and production in that industry has not grown as rapidly as in other fields of engineering, partly because it was so large already at the turn of the century. To young men, the opportunities in the mineral field have therefore appeared more limited than in other fields and they have turned to the greener pastures. Time, however, is catching up with the oldsters and I truly believe that the opportunities here will be very great in the next generation. A difference in emphasis from a descripive approach to a creative engineering approach is now being adopted in mineral engineering schools. It is hoped that this will bring fruit in drawing to the field a fair share of the able young men who will come of age in the years immediately ahead.

In connection with the subject of making ore reserves—as contrasted with finding them—I believe you may find it interesting to read the enclosed copy of an address I gave before the American Association for the Advancement of Science at their annual meeting in Boston, in December 1953. It makes the point, I believe, that an increase in our mineral reserves can come not only by finding new deposits,

but also by so improving technology as to make ore from formerly submarginal materials.

The problem of industrial and domestic scrap utilization is a third topic of importance. In this field, development of a cooperative and experimentative attitude on the part of municipalities is very desirable. To some extent the problem is one of local politics but it is also one of engineering, the scrap heaps being regarded as constantly replenished ore bodies. It would seem as if a pilot community could be selected for the purpose of designing a scrap-recovery process and for then operating a scrap-recovery pilot plant.

It is with some hesitation that I make any reference to the subject of protection of American capital and know-how engaged in operations in foreign lands, lest my observations be misconstrued as unfriendly to our friends outside of the United States. Nothing is really further from my mind than to bring about such a reaction because I strongly believe that the most profitable way not only for ourselves abroad but also for the foreign governments and their peoples is to establish and maintain an attitude of cooperation and mutual respect in the development of the world's mineral resources. The fact is that in many cases mineral deposits abroad have remained unsuspected, undeveloped, or unexploited until American capital or American skill was applied to find, develop, or exploit them. Naturally, this effort abroad of American private enterprise has required much capital and the application of our national engineering talent. This effort has been made in the hope of a material reward by capitalists and engineers. Agreements have usually been concluded between American entrepreneurs on the one hand and foreign owners or governments on the other, for the realization of what at the time was the hope of all. If after the large commitments of capital have been made, and the way to do the job has been worked out, the rules of the game are changed unilaterally, as by expropriation (no matter how disguised), the inevitable effect will be to dampen or prevent foreign development by America's private enterprisers—and foreign resources may well remain mere dreams. This is a place where our foreign policy could be more steadfastly directed at protecting the interests of our nationals abroad. This is not to say that our present foregin policy is not soundly centered but it is generally believed that it has not always been sufficiently concerned with protecting our nationals' foreign interests.

In this communication it has been my purpose to express to you may views in a general manner without specific reference to one material or another. The materials which become critically short from time to time have been varied and will continue to vary. Any pinpointing of one material or another, be it manganese, uranium, tungsten, or cobalt, will then have significance only at some particular time. But the problem is much broader than the needs for any one particular substance, and this is why I have chosen to present suggestions in a general form.

Sincerely yours,

A. M. GAUDIN.

MAKING ORE RESERVES

(By A. M. Gaudin, Richards professor of mineral engineering, Massachusetts Institute of Technology)

Mineral enterprises require ore reserves in order to exploit deposits with foresight. It follows that the geologist plays a major part in providing that balance and planning which make for economy and success. It is not so widely known, however, that the mineral engineer plays an equally important part, not in finding ore reserves but in making them. To introduce the concept of making ore reserves to this great body of scientists and engineers may be stimulating particularly since this art bids fair in the near future to grow even faster than its older and better-known geological brother.

The concept of finding ore goes hand in hand with the idea that the supply is a fixed quantity from which all that man can do is to make withdrawals—just exactly as a person may draw on a bank deposit until the supply of funds is exhausted. If there were no mechanism by which additional deposits could be made to our friends' bank account, it is certain that sooner or later his credit would be exhausted. In the same way, people who are essentially conservationists in point of view imagine that we must protect supplies of mineral raw materials because they cannot be replaced, because they are a wasting asset. Industry's appetite for every kind of metal, fuel, and nonmetallic mineral increases from year to year, almost on a compound-interest basis. It is obvious therefore that if the

classical view of ore supply as a wasting asset were to prevail, the exhaution of the supply would be approached at an accelerating pace, and that the day of reckoning would not be far distant.

A corollary of this classical view of ore supply is that our activity in seeking and finding ores should be going on at an ever-increasing rate and that large stockpiles should be assembled. I do not doubt the wisdom of these measures, but I believe that it is unwise to rest our industrial and national preparedness on the underlying stationary psychology, for it must be conceded that a second corollary of the traditional view of ore supply is pessimism and defeatism for man's ultimate future.

WHAT IS "CONSUMING" A MINERAL SUBSTANCE?

Perhaps in trying to see to what extent this pessimistic outlook is warranted, we might begin by inquiring into just what we mean when we speak of consuming a mineral substance. Of course, the answer may be different when dealing with metallic ores, with fuels, or with nonmetallic, nonfuel minerals. In dealing with metals, consuming does not mean what common usage connotes, but rather exchanging an ore in the ground for a metal in circulation or, in a few instances, for a metal that through use is dispersed in air or in water, for example, the lead that is used in anti-knock gasoline, or iron's rust. In the case of fuels, the consumption is more real because, what is of value in a fuel is not the aggregate of atoms of a lump of coal or a gallon of oil but the ability of the fuel to react with oxygen thereby producing heat. The consumption of fuels therefore results in a lessening of the desirability of the atoms of which the fuel is made, in the sense that steam and carbon dioxide are less desirable than hydrocarbons. The case of the nonmetal, nonfuel minerals is often one in which the valuable property is the physical form of the substance; for example, the physical form of asbestos in long fibrous crystals. In this field, it is entirely practical to look forward to the fabrication of substitutes. Where the nonmetallic minerals are valued for their chemical rather than their physical makeup the primary effect of use is dispersion in the earth's crust—the very opposite of concentration.

Consumption of the mineral substance therefore, in general results in reduction of the degree of concentration of the substance, from that of a deposit in which the desirable entity is relatively localized to dispersion in the atmosphere or in the sea at its worst—or perhaps to the lesser objection of accumulation in scrap piles. It can also be said that to consume a mineral substance means to increase the homogeneity of the earth's crust. The thing that makes an ore deposit valuable is the existence of an inhomogeneity of a grade, volume and situation sufficient to make exploitation of this inhomogeneity commercially attractive. So, while one of the major ways of keeping abreast of needs is to go out and hunt for additional inhomogeneities, it is equally rational to make currently inadequate inhomogeneities adequate by deliberate adaptation to that purpose of physics, chemistry and their offspring sciences. This is one of the major functions of mineral engineering.

In view of the fact that this particular symposium is centered on that most important part of the earth's crust where land, air, and sea come together, it is fitting to limit our discussion to those minerals which are characteristically a product of this border of land and sea. It happens that the principal agricultural minerals, nitrates, phosphate, and potash are found in sediments, that is rocks that generally were laid down in relatively shallow seas. Although sedimentary rocks are the source of many elements other than nitrates, phosphates and potash, the discussion will be limited to these three elements because of their illustrative value.

NITRATES

The case of the nitrates is technologically perhaps the most advanced. For millenia nitrates were added to the soil by working into it organic remains of various kinds, animal or vegetable; this remains to this date an attractive method. Supply of nitrogen in this form however is entirely too limited, so increasing reliance has been placed on inorganic nitrates. Mineral nitrates have come largely from Chile where they occur in a desert region as a dry saline cement in porous sandy sediments. Ground water, occasional rains, evaporation, and transpiration may have formed the deposits. At first the highest grades, only, of the crude "caliche" were mined, the salts being separated from the sands by leaching with hot water and crystallization on cooling. There was no purification nor adequate thermal economy to the process. With increasing availability of byproduct ammonia from the coking of coal, and depletion of the highest

grade caliche came the need for improved methods. These produced valuable by-products and involved better economy of manpower as of fuels. As a result, ore reserves were very materially increased in the Chilean area and the Chilean fields were given a second life. However, even these increased reserves of chemical nitrogen looked insufficient. Furthermore, certain countries of Europe just before and during World War I, being faced with a shortage of nitrogen, turned to the broader problem of synthesizing nitrate from a source available within their borders, namely the air. From this ubiquitous source chemists learned to make cheap ammonia, and other nitrogenous substances. This nitrogen fixation industry has now become much more important than the caliche industry of Chile.

While generally regarded as a chemical industry, is it not equally useful to view nitrogen fixation as a mineral enterprise in which the making of ore reserves has been maximized?

The grade of the ore is now low, less than 2 pounds per cubic yard, but constant, and the tonnage is so large as to beinexhaustible. The ore reserves are politically secure and the operation may be conducted on a completely rational economic basis.

PHOSPHATES

The second example is that of phosphates. In this instance, also, the traditional supply was organic, primarily ground up bones or bonemeal. The supply of phosphate in this form however is very far from sufficient. In recent years guano, phosphate rock, and certain byproducts of metallurgical operations have provided an increasingly large portion of the available phosphate. Of all these sources, the largest and most important is represented by sedimentary phosphate rock formations. These sediments, originally laid down in shallow seas near the border of the land, contained remains of invertebrates and bones and teeth of fish as well as of certain mammals. These natural graveyards constituted the primary reservoirs of mineral phosphate; they were worked over across geologic time through Nature's processes of solution and recrystallization to produce stratified layers, rich in phosphate.

The principal mineral is a saline compound consisting of chloride and fluoride anions with a calcium phosphate complex cation. The mineral generally does not occur as coarse crystals and oftentimes appears to be of colloidal structure hence its name of collophane. It does not occur alone, and is in fact generally associated with much quartz sand, various clay minerals, and aluminous and iron phosphates. Collophane particles are often concretionary in nature, variously fragile and porous ranging in color from white to dark brown and in size from a fraction of an inch to a few microns. The quartz grains are like other quartz sands in beaches and the clay minerals and aluminum and iron phosphates are much finer.

Deposits of this character occur principally in Florida and elsewhere in the world. In the Rocky Mountain area there occurs the extensive Phosphoria formation older in age than the phosphatic strata of Florida and more completely indurated and cemented together, particularly by calcium carbonate. American phosphate resources are also characterized by the occurrence of minor quantities of other elements among which vanadium and uranium are now of considerable importance.

The initial exploitation of mineral phosphate sources again consisted in selecting deposits of the highest grade, the product being marketed without treatment. This is akin to picking plums out of plug pudding whereby much of the fine fruit is lost. Subsequently, the phosphate rock was treated by wet screening, the coarse phosphate nodules being saved as a concentrate. This procedure left a bulky reject containing most of the phosphate along with quartz and the minerals of clay sizes. This exploitation put in waste ponds large quantities of phosphate along with the clay and sand. The tailings therefore did not represent finished waste but rather a product from which part of the cream had been skimmed off.

At this stage, entirely new processes were developed for the recovery of the phosphate particles of fine size, that is particles ranging in size from two millimeters to one-tenth of a millimeter. These processes are the flotation and agglomeration processes. One reason why the phosphate particles could not be recovered appropriately by the former washing and screening process was that they have almost the same specific gravity as the sand. The exploitation of the sandy part of the Florida deposits therefore had to await the invention of a process in which specific gravity would not be the major factor. The flotation

and agglomeration processes have done that by depending for their effectiveness on causing the phosphate particles to stick to air while quartz does not stick, or conversely on having siliceous particles stick to air while the phosphate particles do not. In this way, a suspension consisting of the sand-sized materials was separated into two parts one of which would form either a froth or aerated agglomerates and the other a watery suspension of the usual type. The two parts under the influence of gravity followed different paths, one of them becoming the concentrate.

Flotation and agglomeration, however, have not resulted in a complete answer to the treatment of phosphatic strata and perhaps as much as one-third of the phosphate in the portion treated is lost this time in the form of particles of clay size. At this point, the problem is much more difficult than was the case before and the margin of improvement is smaller so that the incentive for pursuing the problem at this juncture is not at hand. However, the time will come perhaps in a few decades when it will again be urgent to expand our phosphate ore reserves. We can confidently predict that some solution to the problem will be found.

In addition to the phosphate that is being mined and of which a substantial part is now recovered, there are voluminous strata that contain the phosphate largely in the form of the slimy particles of micron size. These deposits are not exploited at present because of their unattractive character; however, as some contain somewhat more uranium than the very low content of the regular phosphate rock, it is likely that their exploitation as a joint uranium-phosphate affair will be realized.

The evolution that I have sketched in regard to the treatment of the phosphate material from Florida brought about large increases in the available ore reserves. This happened at every step, as each new treatment process increased the recovery of the desired product and transformed near-ore into profitable ore. Vast new quantities of near-ore, also were added, thus swelling the future possibilities of each area under exploitation and adding new areas to the roster of possible producers. The increased scale of operations following the use of flotation and agglomeration made for lower costs and therefore a lower price for the product and this lower price for the product has, in turn, been a major factor in increasing the demand. The phosphate industry thus provides a beautiful example of the interdependence of ore reserves, treatment process, price for the product and market.

POTASH

The last example is provided by potash, the third essential agricultural ingredient. For a long time potash, like phosphate and nitrate, was derived from organic sources, in this case largely from plants as the name of potash suggests. Again the demand outran the supply. Then, in the past century a source of potassium salts was discovered in Stassfurt, central Germany. To this circumstance may be given part of the credit for Germany's industrial preeminence in the chemical field.

The processes that were invented and made to flower by German chemists for the treatment of their potassium deposits involved great skill in the thermal control of dissolution and crystallization and in the practical industrial application of the Phase Rule. In particular, in connection with the treatment of ores containing potassium chloride with sodium chloride, the so-called sylvinite ores, the process took rather simple form in that it involved heating the ore with brine to produce a hot brine saturated in regard to both potassium chloride and sodium chloride, separating this liquor from the common salt reject, cooling the brine to crystallize potassium chloride and filtering at low temperature to part the potassium chloride crystals from the cold brine which was reused with a new batch of ore. This heat-leaching and cooling-crystallization process rests upon the physicochemical fact that a brine in contact with both potassium chloride and sodium chloride and saturated with both contains much more potassium when hot than cold, while it contains slightly less sodium when hot than cold.

For a long time this country was deficient in mineral potassium deposits but thanks to proper geological exploration a large Permian basin was discovered in the Carlsbad area of New Mexico. At present, exploitation is concentrated on those horizons in which the potassium chloride occurs with sodium chloride and a little clay, that is sylvinite ores, although the future will no doubt see the major development of horizons in which the principal valuable minerals are polyhalite, carnallite, langbeinite, and other complex potassium salts.

For the New Mexico sylvinite ores the German process is entirely feasible, but a more economic process was developed through American ingenuity. This combines the advantages of flotation operation with those of crystallization. The mixture of potassium chloride and sodium chloride is aerated as an aqueous slurry after appropriate organic compounds have been added to the pulp. This waterproofs one or the other of the salts, and the waterproofed particles stick to the bubbles to form a froth. For example, by using relatively minute quantities of dodecyl or hexadecyl amine salts and starch, it is possible to cause the potassium chloride particles alone to float attached to air bubbles in a brine saturated in respect to both potassium chloride and sodium chloride while the sodium chloride and the clay are maintained in the wetted state in the suspension. The process is not just a straight flotation process because of the solubility of the minerals and because of the variations in solubility with temperature, in fact, because of those very attributes which made the German process possible before the invention of this flotation process. In the latest expression of the flotation process for the treatment of the New Mexico ores, the recovery of the valuable constituent is obtained in part through flotation and in part through a heat-leaching and cooling-crystallization cycle. The process is now adopted and used in Europe as well as here.

One of the effects of introduction of the potash floating processes has been to lower the relative price of the potassium salts. A second effect has been to make possible the treatment of materials which formerly could not be touched because of their complexity or poverty and a third effect has been to increase the demand for this cheaper potash.

Eventually the process of treatment of potassium salts will be extended to other sources than solid potassium minerals. In fact, there are already two operations that depend on the waters of Searles Lake, Calif., and Great Salt Lake, Utah, for their potassium. These waters are enriched compared to the ocean and they contain salts other than of potassium in proportions different from those occurring in the ocean. The Great Salt Lake brines are allowed to crystallize in such a way as to form mixtures of potassium chloride and sodium chloride, and the mixed salts are then handled like the sylvinite ores of New Mexico. Plans are afoot in Palestine for exploiting the potassium from the Dead Sea: this proposal would increase vastly the supply of agricultural fertilizer for a large part of the Near East where the soils have been depleted by millenia of human culture and human abuse. Finally, the plans are afoot also to recover potassium from sea water, this time by using another novel process, invented in Norway, which includes as one of the steps, the removal of the potassium from sea water by a selected ion-exchange resin. This ion-exchange resin would abstract potassium in exchange for sodium or hydrogen whereas at a later step, the resin would be regenerated by treatment with appropriate solutions of common salt or of acid. In this way, a cyclic operation would result with production of an enriched potassium brine as its direct aim. Thus, the prospect exists of extending our ore reserve of potassium to the entire mass of the ocean. Such an ore reserve would inevitably assure us forever against a deficiency of potassium not only because it is so vast and so uniform in grade, but also because everything eventually returns to the sea.

CONCLUSION

Thus, after a long evolution with land as our home and our source of all good things, we are perhaps reverting to our mother, the sea. This mother is really the inexhaustible source of all minerals. It is vast. It is relatively constant in composition and it touches most countries. The reserve of the sea for some minerals is already being drawn upon. I have in mind magnesium and bromine which are extracted by two different processes. The magnesium is extracted by causing sea water to pass over calcined oystershells. The lime reacts with magnesium to produce a precipitate of magnesium hydroxide and places the calcium in solution. The magnesium hydroxide is then settled and filtered off, and from it metallic magnesium is made by electrolysis. The bromine is extracted by adding to sea water an organic compound containing chlorine, the process depending on the fact that the organic chlorine compound reacts with dissolved bromine in sea water to form the comparable organic bromine derivative while the chloride ion takes the place of the bromide ion in the water. The organic bromine compound is insoluble and is removed by filtration.

Obviously both magnesium and bromine processes require in their engineering application the handling of huge quantities of sea water. One of the principal

features of the new mineral engineering is precisely this item of handling huge quantities of water, causing it to do such simple things as settling, filtering, or floating. We all know that sea water contains gold. Some of us have read that it contains uranium and, in fact, that it contains some quantity of nearly all elements. By the adaptation of processes for the removal of solutes, in particular by such processes as solvent extraction and ion exchange, it may be possible to draw on the sea for many elements other than bromine, iodine, magnesium, or potassium. These four are just the beginning of what may become the longest list of mineral products yet to come from any one source.

The development of which I speak is one that depends on the concept of making out of the sea an ore reserve of inexhaustible size. When the day has come that we can draw from this source all the elements that we need, we will no doubt be achieving a technology that is of a different order than the one that we now have, with a stability of industrial production that we can hope for now but cannot realize. The promise of technology in the field of mineral materials is therefore not one that should lead us to look only to the earth's crust but also to view the sea and the air as our ultimate reservoirs.

CORNING GLASS WORKS,
Corning, N. Y., November 10, 1954.

Hon. GEORGE W. MALONE,
Chairman, Minerals, Materials, and Fuels Economic Subcommittee,
United States Senate, Washington, D. C.

DEAR SENATOR MALONE: At the request of your staff engineer, Mr. George B. Holderer, we have prepared the attached statement which we wish to have read into the record of your open committee hearings on the subject of substitutes, replacements, and synthesis of critical materials.

Corning Glass Works deals primarily with raw materials of an abundant and noncritical nature, and this fact has focused attention on our products as replacements for more critical metals, ores, or remote foreign sources of glass. We have worked closely with industry and the armed services in the past and shall continue our cooperative development of processes and products that release highly strategic materials.

Please call upon us if any clarification or amplification is needed on any points covered by our attached statement.

Very truly yours,

CAMPBELL RUTLEDGE, Jr.,
General Sales Manager, New Products Division.

1. This is a statement by Corning Glass Works proposed for open hearings November 10–11, 1954, of the Subcommittee on Minerals, Materials, and Fuels, United States Senate, on the subject of substitutes, replacements, and synthesis of critical materials.

2 (*a*). Corning Glass Works is a corporation established under the laws of New York State, founded in 1851 in Massachusetts, and having headquarters offices and plant in Corning, N. Y., since 1868. Principal officers of the company are Amory Houghton, chairman; Glen W. Cole, vice chairman; William C. Decker, president; Charles D. LaFollette, vice president and treasurer; George D. Macbeth, vice president and controller; Frederick H. Knight, secretary; and John L. Hanigan, Russell Brittingham, John Carter, and Thomas Waaland, vice presidents.

(*b*) In addition to Corning, N. Y., plants are operated in Wellsboro, Bradford, and Charleroi, Pa.; Central Falls, R. I.; Parkersburg, W. Va.; Danville and Harrodsburg, Ky.; Albion, Mich.; and Muskogee, Okla. The company employs approximately 14,000 people in all domestic operations. Stockholders number 6,488.

(*c*) Corning Glass Works, Ltd., of Leaside, Ontario, is a wholly owned subsidiary producing baking ware and tableware. Steuben Glass, Inc., is a wholly owned subsidiary marketing fine crystal ware. Corning Glass Works has substantial interests in the following domestic companies: Owens-Corning Fiberglas Corp.; Dow-Corning Corp.; Pittsburgh-Corning Corp.; Corhart Refractories Co.; Corning Fiber Box Corp.; and Blue Ridge Glass Co. Minority stock interests are maintained in these Central and South American glass manufacturers: Cristalerias Rigolleau, S. A., Buenos Aires, Argentina; Cia. Vidraria Santa Marina, S. A.: São Paulo, Brazil: Cristalerias De Chile, S. A., Santiago, Chile; and Cristales Mexicanos, Monterrey, Mexico.

3 (*a*). In 1953 Corning Glass Works had total sales of $149,294,036. Principal product lines are baking and cooking ware, tableware, television bulbs, lamp and radio bulbs, fluorescent tube bulbs, laboratory glassware, thermometer tubing, optical and ophthalmic blanks, lighting ware, piping, gage glasses, and miscellaneous industrial glassware. Principal trade marks are "CORNING," "PYREX," and "VYCOR."

(*b*) In 1953 the company spent $5,220,558 for research, or 3.5 percent of the sales dollar. This rate of research expenditure is double all industry averages and substantiates a current company advertising slogan, "Corning means research in glass."

4 (*a*). Replacing critical materials with noncritical glass is a constant process generated by necessity, costs, and development of more useful glass compositions or more serviceable end products. Pyrex piping is a good illustration of all of these reasons. A pilot-plant curiosity in the 1930's, Pyrex pipe came of age during World War II when it was widely specified by chemical, munitions, and food-processing plants as a replacement for stainless steel, copper, lead, and other critical piping materials. Many miles of glass pipe helped convey corrosive chemicals in the big Oak Ridge operation of Manhattan project. Less spectacular but quite important were the many installations in dairies and canning plants that kept milk and food products flowing under protected sanitary conditions.

Subsequent technical developments improved and strengthened Pyrex pipe so that today it is widely known and used throughout the chemical, food-processing, and dairy industries. For every 100 feet of installed glass pipe, a plant can save critical metal as follows:

Average savings in pounds

100 feet of glass pipe	18–8 stainless steel	Lead	Copper
1½-inch diameter	271	500	319
2-inch diameter	365	700	422
3-inch diameter	775	1,250	874
4-inch diameter	1,079	1,640	1,293

Recognizing these important potential savings, health authorities, legislative bodies, and the dairy industry have all cooperated to bring about changes in sanitary codes that now permit the use of permanent glass pipelines in dairy plants, thus releasing 18–8 stainless steel for more important applications where no really suitable replacement is available. This year (1954) the dairy industry alone will save over 500,000 pounds of stainless-steel tubing by installing glass lines. Under wartime emergency when the need for replacement of metal might become acute, the annual saving could easily exceed 1 million pounds of stainless steel.

Estimates we made in 1951 for the Defense Production Administration and the National Production Authority are still considered valid, if possibly conservative: at least 6 million pounds of stainless steel, copper, and lead (all 3 being very critical at the time) could be saved each year if the chemical, food processing, dairy, and brewing industries were to specify glass pipe for many of their fluid transportation lines.

Fortunately for industry, replacement of metal lines by glass pipe generally results in overall savings, sometimes of a very substantial amount. Such savings coupled with improvements in glass pipe and its availability make the replacement attractive.

(*b*). During the last war Corning Glass Works was asked to get into the optical glass business to produce much needed parts for the armed services. Demand for binoculars, camera lenses, fire control prisms, and other items far exceeded existing domestic glass capacity, and we were, of course, shut off from the German producers who had traditionally supplied much of this Nation's needs. We not only got into the optical glass business, but in doing so developed radically new melting and forming techniques which revolutionized the industry and saved money for our Government and its contractors. Corning has continued in the optical business and is now one of the major suppliers to the trade, helping make this Nation independent of foreign supplies of optics.

(*c*). Our Nation is entirely dependent upon foreign sources (principally India) for quality mica that is essential for many electrical appliances and electronic

components. Very high grade mica is needed to make capacitors, an important electronic device. Realizing the predicament industry and the armed services would be in if mica supplies were cut off, the United States Navy and the Signal Corps have encouraged Corning Glass Works to develop all-glass capacitors that will replace mica capacitors. Six years of hard work by a large research staff have made the all-glass capacitors a reality and these units are now being used in increasing quantity for construction of electronic circuits.

Like so many other replacement items developed to substitute for a critical material, the glass capacitor outperforms its mica counterpart. Everything a mica capacitor does, the glass replacement will do better. It will operate at higher temperatures, it can be made in smaller sizes, it is impervious to humidity, it will have indefinite shelf life, it is capable of exact retrace, and is stable and predictable under widely varying operating conditions. Equally important, in the long run it should be made cheaper than a mica capacitor.

5 (*a*). Currently we are working on another problem that should result in savings of critical nichrome wire. For the Signal Corps we have undertaken the development of pilot facilities to produce power-type resistors made of an oxide-resistance film deposited on glass rods or tubes. The oxide-resistance film replaces wire-wound resistors and could save millions of pounds of nichrome in time of war emergency. Also, such resistors hold promise of having greater operating range and should eventually be lower in cost than comparable wire-wound types. This will mean direct dollar savings to industry and the armed services as well as material savings.

6 (*a*). As a company we are always very much interested in developing and promoting new uses for glass. Constant research on composition has yielded thousands of formulas upon which we can draw when a glass of special properties is required. Our product development engineers are constantly applying their knowledge to help customers utilize glass parts to fullest advantage. Many applications for glass parts are for replacements of critical materials arising either from ideas of our own or the problems prospective customers bring to us.

We are fortunate to be dealing with noncritical raw materials, most of which are in abundant supply in our own country. With the great progress made in composition, research, melting, forming, and strengthening techniques, glass is a useful and valuable replacement today for many critical materials. Corning Glass Works hopes to make it even more useful and more widely used.

(Corning Glass Works submitted for the record a pamphlet showing the use of Pyrex brand glass pipe in (1) chemical process industries; (2) distillation of special hydrocarbons; (3) alkaline organiz solvent and muriatic acid; (4) chlorinated hydrocarbons; (5) sensitive pharmaceuticals; (6) disposal of corrosive waste gases; (7) processing photographic chemicals; (8) corrosive solvents; (9) chlorinating an organic at 100° C.; (10) delicate pharmaceuticals; (11) food processing; (12) vinegar; (13) pulped fruit and vegetables; (14) processed fruits and vegetables and juices; (15) baby foods; (16) conveying brines; (17)tomato products; (18) wine industry; and (19) dairy industry.)

CORNING FIXED GLASS CAPACITORS FOR MAXIMUM RELIABILITY AND ELECTRICAL STABILITY AT HIGH TEMPERATURES

Developed through Corning research, these truly miniature fixed glass capacitors possess outstanding behavior characteristics that suggest use in critical applications and under high temperatures.

In addition, the glass used has several unique properties which make these capacitors especially desirable for many new and critical applications.

The superior electrical insulating properties of the glass used are more like those of mica than any other commonly used capacitor dielectric.

The glass dielectric material is formed as a homogeneous, continuous ribbon, entirely free of holes, cracks, foreign inclusions, and many other imperfections. After assembly, the many layers of conductor and dielectric of the capacitor are sealed together at a high temperature and pressure as an integral, rugged monolithic unit. The seal of the electrodes to the dielectric sheets cannot be broken or shifted without destroying the capacitor. Thus, the properties of the capaci-

tor are those of the closely controlled dielectric, and are not determined by assembly method or affected by any subsequent treatment.

Glass capacitors may be assembled with wire leads and an enclosing glass cover having the same superior electrical properties as the dielectric glass. Thus, its performance is a function only of the dielectric properties of the glass, and not of any enclosing or potting material or impregnant. As a result, the capacitor may be considered particularly useful in many new high-temperature applications.

MINIATURIZATION

The glass capacitor offers a higher degree of miniaturization than any other high-quality capacitor on the market. As a result there is reduction in number of physical sizes to cover a large capacitance range. There is also a reduction in the minimum practical size; the volume of case size CY10 is about .005 cubic inches. For capacitors without wire leads, the size can be further reduced; the active volume of a CY10 200 uuf capacitor being less than 10% of this amount. Single sealed capacitors of this kind, up to at least .1 ufd, are finding wide application.

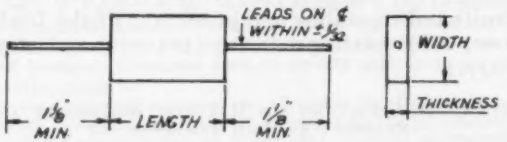
Wide latitude of equipment design is possible when using Corning Fixed Glass Capacitors. They can be made to meet the electrical and physical specifications of any particular application. High capacitances or high voltages can often be designed into a single, self-supported unit; series-parallel combinations extend the range still further.

Because the layers of conductor and dielectric and the enclosing cover are a single monolithic structure, the dependence of capacitance on temperature will be the same for every capacitor (Table I). The temperature coefficients of capacitance derived from this curve are shown (Table II). The temperature coefficients as shown by these curves is not a straight line function. However, it should be noted that the temperature coefficient as determined by measurements at 25° C. and 85° C. is $+140 \pm 25$ parts per million /°C. Capacitance drift is very nearly zero, and does not exceed $\pm .1\% + .1$ mmf.

SIZES

Glass capacitors are available in the case sizes shown in Table I. The dimensional ranges shown are those currently experienced in production. Limited quantities are available in the smaller sizes shown in military specifications, MIL–C–11272A. With the improvements presently contemplated in manufacturing techniques and methods, it is expected that the sizes of the capacitors will be reduced to those of MIL–C–11272A.

TABLE I



CASE	LENGTH	WIDTH	THICKNESS	WIRE SIZE
CY10	5/16"-27/64"	9/64"-15/64"	3/64"-7/64"	#26 AWG .016"
CY15	27/64"-35/64"	15/64"-21/64"	1/16"-5/32"	#22 AWG .025"
CY20	43/64"-57/64"	3/8"-1/2"	3/32"-3/16"	#20 AWG .032"
CY30	43/64"-57/64"	43/64"-53/64"	3/32"-3/16"	#20 AWG .032"

CAPACITANCE AND VOLTAGE RATINGS

Glass capacitors are available in the sizes, voltage ratings and capacitance values shown in Table II. These are conservative ratings based on 100% survival in life tests at 85° C. and may later be revised upward.

TABLE II (*capacitance uuf*)

Size	300 VDCW	500 VDCW
CY10	1-240	1-150
CY15	200-1200	100-510
CY20	1000-5100	510-3600
CY30	3000-10000	3000-5600

CAPACITANCE TOLERANCE

Standard tolerance is ±10%. Also available in closer tolerances, however for capacitances up to and including 10 uuf, the minimum tolerance is ±½ uuf and for all other capacitances ±1% or 1 uuf, whichever is greater.

INSULATION RESISTANCE

The insulation resistance exceeds 10,000 megohms when measured with a DC potential equal to the voltage rating of the capacitor, at a temperature of 25° ±5°C., and a relative humidity of 80 per cent or less.

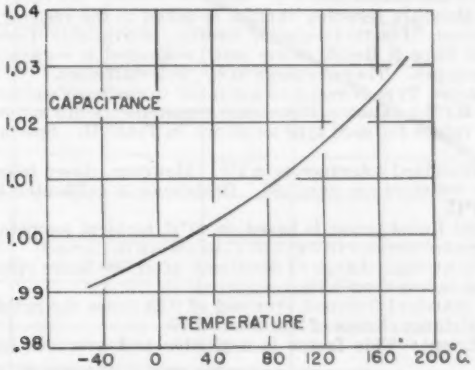


FIGURE 1

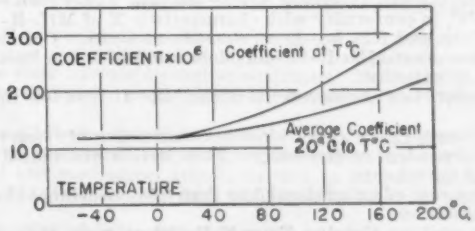


FIGURE 2

Corning Film Type Resistors Style N

MIL–R–10509A SPECIFICATIONS—ACCURATE, STABLE, ECONOMICAL

Corning N Type Resistors are especially designed for close-tolerance applications with economy in mind. They are made of PYREX brand glass rod to which is fused a thin film of equally rugged metallic oxides. Core and film are inseparably impervious, and stable under the most adverse operating conditions.

While precision resistance is the keynote for Corning N Type Resistors, they have added benefits which include a noise level which is so low that it is difficult to measure. They have low voltage coefficient, and low inductive and capacitive reactance, as well as extremely high stability.

Corning N Type Resistors have overcome the inherent inadequacies of conventional type resistors in many advanced circuits. They are recommended for:

(1) circuits in which carbon composition resistors are unsuitable, and wirewound resistors are too expensive or unsuitable.

(2) radio and television equipment, high-frequency circuits, test equipment, and in particular low signal-level, hi-gain amplifier stages.

SPECIFICATIONS

Resistance Element: Accurate, stable Corning E-C coating fused to PYREX brand glass core meets the most exacting circuit needs. Rugged performance does not depend on encapsulation. For sizes, ranges, and other data see Figure 1, and Tables I and II.

Terminals: Silver-plated brass caps are expansion fitted over bands of silver, fired to the resistance coating to provide a silver-to-silver contact.

Leads: Hot-tinned axial leads 1½" long are securely fastened to caps.

Insulation: Moisture resisting varnish is baked to the resistor for added mechanical protection. Plastic insulating sleeves are available if desired.

Size: Corning Type N Resistors are small compared to encapsulated and hermetically sealed types. They are made in ½-, 1-, 2-watt sizes.

Resistance range: Type N resistors are made to customer's exact specifications rather than to RTMA values. Resistance requirements are subject to minimum and maximum values for each type as shown in Table II. Special requirements can be met.

Tolerance: Standard tolerance is ±1%. However, closer tolerances, as well as 2% and 5% resistors are supplied. Resistance is calibrated to the specified tolerance at 25°C.

Power ratings: Rated power is based on 40°C. ambient temperature. Style N resistors are derated linearly to 0 at 140°C. as shown in Curve 1.

Stability: The average change of resistance after 500 hours operation at maximum dissipation is less than 0.5%

Overload: A standard 5-second overload of 6.25 times the rated power causes a permanent resistance change of less than 0.75%

Voltage coefficient: This factor is negligible and averages less than .001% per volt.

Maximum voltage: Type N20 carries 350 VDC, N25—500VDC, and N30—750 VDC continuously. Momentary peaks of 10 times the specified voltage can be carried without breaking down. For low-resistance values the voltage should be reduced to the limits of the wattage rating.

Temperature coefficient: The value of temperature coefficient in the range from 25 to 85°C. is less than ±.035% per degree C. It varies slightly with temperature. In no instance will TC exceed +350—500 ppm °C. between —55 to +105°C. reference to 25°C. in conformity with characteristic X of MIL–R–10509A.

Humidity: Core and film are impervious to moisture. Corning Type N Resistors more than meet MIL–R–10509A Moisture Resistance Tests without protective coating or capsules.

Noise characteristics: Noise level is negligible. It is so low that it is hard to measure.

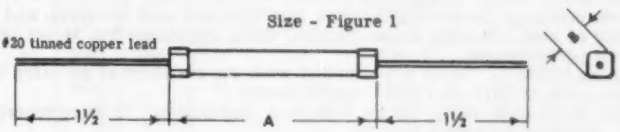
Frequency characteristics: The thin film construction of these resistors makes them largely independent of frequency. They have a distributed inductance no greater than 0.1 microhenry.

Shelf life: One year of aging shows less than 0.5% resistance change under the most adverse conditions.

Temperature cycling: Corning Type N Resistors more than meet the tests specified under MIL–R–10509A.

CORNING FILM TYPE RESISTORS STYLE S

Size - Figure 1

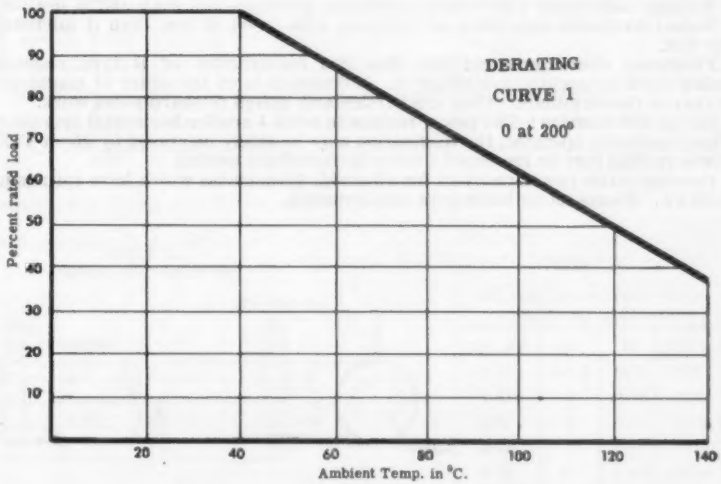


Size – Table I

Style	Inches	
	A	B
S20	19/32	11/64
S25	15/16	19/64
S30	2-1/16	19/64

Range – Table II

Style	Watts	OHMS	
		Min.	Max.
S20	1	10	40K
S25	2	10	30K
S30	4	20	100K



CORNING HIGH-POWER RESISTORS

CORNING R TYPE HIGH-POWER 2% RESISTORS OFFER EXCEPTIONAL PERFORMANCE—AVAILABLE UP TO 1 MEGOHM TO MIL–R–11804A SPECIFICATION

Corning type R power resistors have a range of 25–1,000,000 ohms, ratings of 7–115 watts, and are noninductive. They are designed for stable long-life service under the most adverse operating conditions. Noise and frequency characteristics are exceptionally good. Moisture resistance and overload capacity are superior.

Cores: The glass tube cores are made from a Pyrex brand glass insuring highest resistivity even at elevated temperatures, low expansion, and unusual resistance to chemical and mechanical attack, as well as thermal shock. The cores are impervious, and the glass has been developed to eliminate electrolysis and voltage creepage.

Resistance film: The resistive film of metallic oxides is as rugged as the glass. It is permanently and integrally bonded to the core at red heat. Expansions are matched. The film is practically noninductive at all usable frequencies.

Terminals: Silver metallized bands are fired onto the film conductor and core. Lug-type terminals of silver-plated beryllium copper strip are expansion fitted over the silver bands to insure a perfect electrical and mechanical junction.

Silicone coating: The coating is tough, moisture and acid resistant, and a good conductor of heat. It adds to the thermal shock resistance but is not essential to overall performance.

Mounting brackets: These are supplied with the resistors at no extra charge. They are made to MIL–R–11804A requirements.

Range: Resistance range varies with size and power. It is summarized on table I. Standard tolerance is ±2%.

Ratings: Power ratings are based on 25° C. operating ambient. Maximum operating ambient may be as high as 200° C. and hot spot temperature 225° C.

Derating: At ambient temperatures higher than 25° C., type R resistors should be derated according to figure 1.

Temperature coefficient: The value of temperature coefficient in the range of 25–85° C. is less than ±.035% per deg. C. Type R resistors meet the requirements of MIL–R–11804A.

Stability: The average change of resistance after 500 hours operation at maximum dissipation at 25° C. ambient is 2%.

Overload: A standard 5-second overload of 6.25 times the rated power causes a permanent resistance change of less than 2%.

Humidity: Type R resistors more than meet the specifications for maximum resistance change of MIL–R–11804A.

Voltage coefficient: The voltage coefficient averages less than .001% per volt.

Noise: Available data show an inherent noise level of less than .1 microvolt per volt.

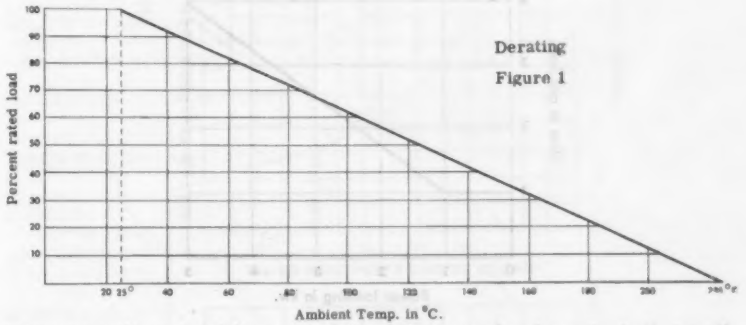
Frequency characteristics: The thin film construction of R type resistors makes them inherently noninductive. Inductance is of the order of magnitude of that of the terminals. They are particularly suited to sharp pulse work.

Design information: The power ratings in table I are for horizontal operation. When vertically operated, the dissipation may be safely increased by about 12%. Power ratings may be increased 4 times by forced air cooling.

Corning builds power resistors for all usable frequencies which have ratings up to 50 kw. Please let us know your requirements.

TABLE 1

Style	Rated Watts	Ohmic Values Min.	Ohmic Values Max.	Temp. rise at rated load in Centigrade	Max. Oper. temp. in Centigrade
R 31	7	10	70,000	200	225
R 33	13	30	150,000	200	225
R 35	25	20	300,000	200	225
R 37	55	20	500,000	200	225
R 39	115	40	1,000,000	200	225



Derating

Figure 1

STYLE R
CORNING E-C RESISTORS

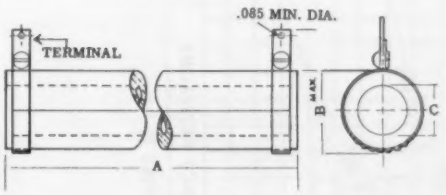


TABLE II

SILICONE PROTECTIVE FINISH APPLIED TO RESISTORS			
STYLE R	A	B	C Min.
R 31	1-1/2	9/16	1/4
R 33	3	9/16	1/4
R 35	4	7/8	15/32
R 37	6	1-1/4	11/16
R 39	12	1-1/4	11/16

Corning Water-Cooled Resistors

TYPE WC5 "WHIRLPOOL" 5 KW. RESISTOR FOR HIGH-FREQUENCY—HIGH-POWER TV, FM, LOW-REACTANCE APPLICATIONS

Design: The mechanical design permits direct mounting on the end of a 3-inch coaxial line with both water intake and outlet connections at RF ground potential. Resistor elements are interchangeable. Different values for service replacements can be readily installed in the field. Two type WC5 units may be operated in series to provide a balanced line termination. Installations requiring power dissipation greater than rating may be handled by using several resistors in parallel.

Operation: The CGW type WC5 resistor is cooled by a high-velocity stream of water flowing in a spiral path against a thin film of resistance material. High-power dissipation is made possible by centrifugal force holding the water in intimate thermal contact with the entire resistance surface. Interchangeable intake nozzles permit adjustment of the rate of water flow, as well as the cooling action,

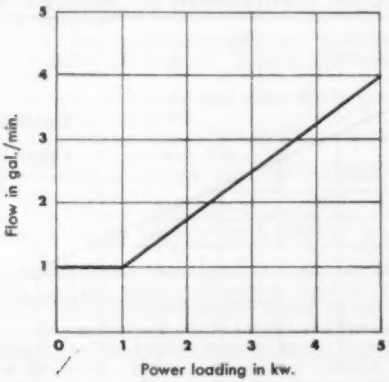
to suit local water pressure and power dissipation up to 5 kw AC. See figures 2 and 3, and table 1.

Frequency characteristics: Skin effect is negligible for all usable frequencies because the resistance film thickness is much smaller than the depth of penetration. The impedance characteristics are shown on table 2. Operation below ½ mc is not recommended. DC operation destroys the resistance film.

Range: 35–300 ohms with ±15% is standard. 10 and 5% tolerance available at extra cost.

Derating: The power input to each resistor element must be limited by the derating curve of figure 1. A minimum flow of 1 gallon per minute must be maintained for any power under 1 kw.

FIGURE I



Power dissipation: Loads up to 5 kw AC are possible, depending on water flow. Flow depends on pressure differential and size of nozzle as shown.

Water temperature rise for 1, 2, and 5 kw power dissipation at different flow rates is shown. Input water 40°C. maximum.

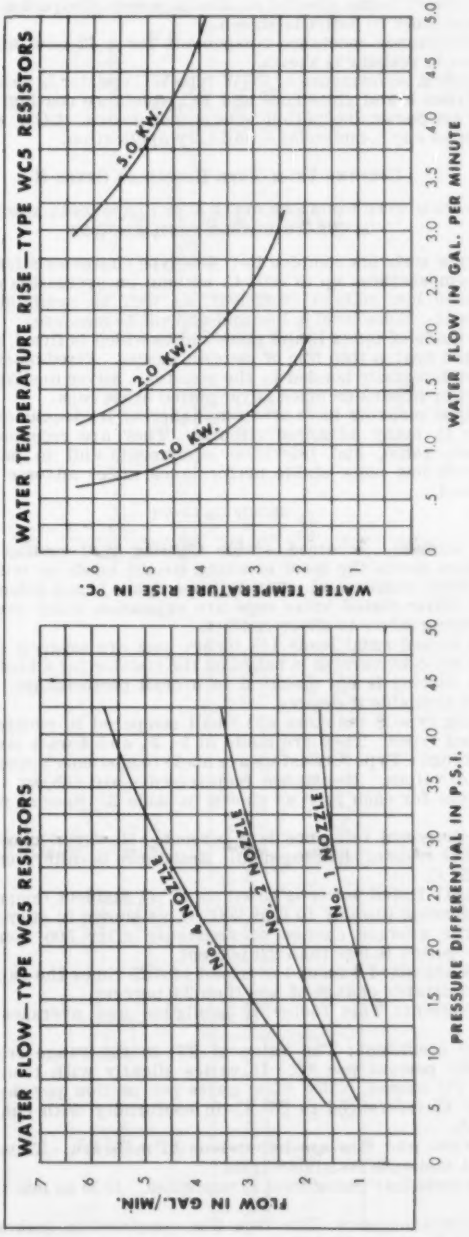

WATER TEMPERATURE RISE—TYPE WC5 RESISTORS
5.0 KW.
2.0 KW.
1.0 KW.
WATER TEMPERATURE RISE IN °C.
WATER FLOW IN GAL. PER MINUTE
0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
6 5 4 3 2 1

FIGURE III

WATER FLOW—TYPE WC5 RESISTORS
No. 4 NOZZLE
No. 2 NOZZLE
No. 1 NOZZLE
FLOW IN GAL./MIN.
PRESSURE DIFFERENTIAL IN P.S.I.
0 5 10 15 20 25 30 35 40 45 50
7 6 5 4 3 2 1

FIGURE II

Table 1.—Correct nozzle size for maximum power dissipation with given pressure differential inlet to outlet is shown.

Table 2.—Resistance reactance components for a 72 ohm unit measured dry and with water in resistor is shown.

The outstanding performance of CGW type WC resistor is based on the ruggedness of the Pyrex brand glass core and EC resistance coating. We build units with up to 50 kw power dissipation to customer design. CGW will be pleased to work with you on any commercial or military application.

Corning Film Type Resistors Style S

CORNING FILM TYPE RESISTORS STYLE S—MIL–R–11804A SPECIFICATIONS, ACCURATE, STABLE, HIGH AMBIENT

Corning S type resistors combine E–C film type characteristics with stable performance at temperatures up to 200° C. without encapsulation or hermetic sealing. They have low voltage coefficient, as well as negligible inductive and capacitive effects. Noise level is low and difficult to measure.

The core is made of pyrex brand glass rod to which is fused, permanently and integrally at red heat, a thin film of metallic oxides. Fired-on silver termination bands are also integrally bonded to the resistor. Silver-to-silver low noise contact is ensured by expansion fitted silver-plated brass caps.

Corning S type resistors have overcome inherent inadequacies of conventional type resistors in many advanced circuits. They are recommended for: high frequency, test, radio, and television equipment, and in particular, hi-gain amplifiers where low noise stable performance under adverse operating conditions is required.

SPECIFICATIONS

Resistance element: Accurate, stable Corning E–C coating fused to pyrex brand glass core meets the most exacting circuit needs at temperatures up to 200° C. For sizes, ranges, and other data see figure 1, and tables 1 and 2.

Terminals: Silver-plated brass caps are expansion fitted over fired-on silver bands to provide a silver-to-silver contact.

Leads: Hot-tinned axial leads 1½ inches long are securely fastened to caps.

Insulation: Silicone varnish is baked on the resistor for added mechanical protection. This coating is not essential to overall performance. Plastic insulating sleeves are available if desired.

Size: Corning type S resistors are small compared to encapsulated and hermetically sealed types. They are made in 1-, 2-, and 4-watt sizes.

Resistance range: Type S resistors are made to customer's specifications rather than to RTMA values. Resistance requirements are subject to minimum and maximum values for each type as shown in table 2. Special requirements can be met.

Tolerance: Standard tolerance is 2 percent. However, closer tolerances, as well as 5 percent resistors are supplied. Resistance is calibrated to the specified tolerance at 25° C.

Power ratings: Rated power is based on 40° C. ambient temperature. Style S resistors are derated linearly to 0 at 200° C. as shown in curve 1.

Stability: The average change of resistance after 500 hours operation at maximum dissipation is less than 2.0 percent.

Overload: A standard 5-second overload of 6.25 times the rated power causes a permanent resistance change of less than 2.0 percent.

Voltage coefficient: This factor is negligible and averages less than .001 percent.

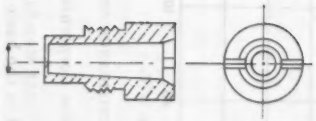
Temperature coefficient: The value of TC in the range from 25–85° C. is less than ±.035 percent per °C. It varies slightly with temperature. In no instance will TC exceed +350 −500 parts per million per degree C. between −55 to +105° C. referenced to 25° C. in conformity with characteristic X of MIL–R–11804A.

Humidity: Core and film are impervious to moisture. These resistors meet MIL–R–11704A moisture resistance tests.

Noise characteristics: Noise level is negligible. It is so low that it is difficult to measure.

Frequency characteristics: The thin film construction makes these resistors inherently noninductive. Distributed capacity is less than 0.5 micromicrofarad.

Diam. "A"

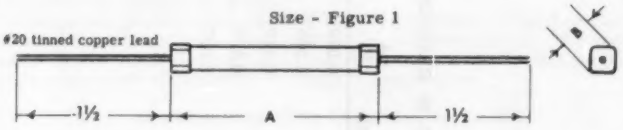


Nozzle	Diam. "A"	Water Flow Gal. Per Min.	Pressure Diff. Inlet to Outlet	Maximum Power
1	0.109"	1	20 Lb. Per Sq. In.	1 kw
2	0.156"	2	16 Lb. Per Sq. In.	2 kw
4	0.203"	4	22 Lb. Per Sq. In.	5 kw

RESISTOR -- DRY			WATER IN RESISTOR		
Megacycles	$+jx$ Z_o	R Z_o	Megacycles	$-jx$ Z_o	R Z_o
60	0.03	0.955	60	0.070	1.01
80	0.07	0.993	80	0.085	1.04
180	0.08	1.082	100	0.110	0.97
200	0.06	1.117	180	0.100	0.845
			200	0.087	0.800

CORNING FILM TYPE RESISTORS STYLE N

Size - Figure 1

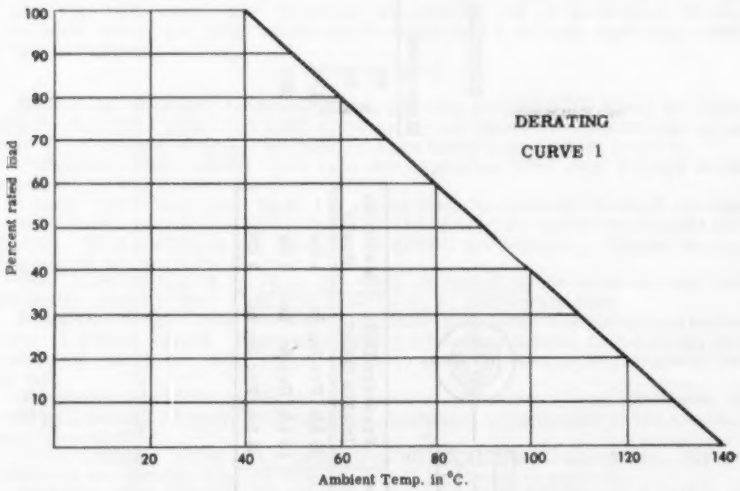


Size – Table I

Style	Inches	
	A	B
N20	19/32	11/64
N25	15/16	19/64
N30	2-1/16	19/64

Range – Table II

Style	Watts	OHMS	
		Min.	Max.
N20	1/2	10	10K
N25	1	10	40K
N30	2	20	100K



Summary of the Development and Significance of Synthetic Mica

(By Jerome Taishoff, president, Mycalex Corporation of America)

This month, November 1954, marks a significant step forward in the unending drive to make the United States self-sufficient in the basic materials vital both to its peacetime economy and its wartime effectiveness.

On November 3, the Mycalex Corporation of America broke ground at West Caldwell, N. J. (on a 15-acre plot, which will ultimately accommodate 150,000 square feet of manufacturing space), and construction of the world's first synthetic mica plant—the Synthetic Mica Corp.—is now underway.

This occasion marks both a beginning and an end. It begins what we at the Mycalex Corp. know will be an important new industry, an industry that can provide, in peace and war, an indispensable material—synthetic mica.

The building of this plant also signifies the end of many years of experiment, of laboratory work, of pilot-plant operation, years in which a handful of scientists, Government technicians, and businessmen worked to develop a practical

synthesis of mica. The period of experimentation is now over. Production of synthetic mica is today not only possible and practical, it is essential. What is being built on the 15-acre site in New Jersey is neither a laboratory nor a pilot operation, but a plant designed for an annual productive capacity of 1,000 tons of high-grade synthetic mica.

While the obvious and primary interest of the Mycalex Corporation of America is to provide for its own requirements, much of this output will go to other industrial firms so that they may make full use of its properties and perhaps add their own years of productive experience to its application. In this manner, and through their own continuing research efforts, the infant synthetic mica industry, now represented only by one plant under construction, will develop the full potential we know it has.

I would like to review briefly how and why this new industry came into being.

The importance of mica is well known. It has become synonymous with effective electrical insulation—in household appliances, in radios, in television and, more important, in many of the classified projects of the armed services, such as in radar, guided missiles, aircraft power, communication, and fire control. Most important of all, mica, when bonded with glass in the special Mycalex process, has been accepted as one of the best all-round insulating materials for nuclear applications. In this age of electronics and nucleonics, mica is an insulator without substitute. Perhaps because it is so vital, like the air around us, most of us have taken it for granted.

Unfortunately, little high-grade mica is mined in the Western Hemisphere. Some 95 percent of the high-grade mica—the mica on which the electric, electronic, and nucleonic power arms of our national defense must rely—is imported from India.

How long this market will remain open should war be thrust upon us is problematical. In this age of the long-range bomber, however, it would be hazardous to rely on raw materials obtained from even our stanchest allies. The search for synthetic mica, in effect, has been a search for insurance, insurance against a shortage of a critical material in a time when it will be most needed—in wartime.

In the closing months of the Second World War, the Germans, as their communication systems began to disintegrate, worked frantically to develop a synthetic mica to replace the natural substance as an effective electrical insulating material. The Germans got to the pilot-plant stage when the war ended.

American industry entered the synthetic-mica picture as the Germans left it. Eventually the United States Government took a hand in the work, and the project was assigned to the Bureau of Mines, Eectrotechnical Laboratory at Norris, Tenn. The Bureau of Ships, Office of Naval Research, National Bureau of Standards, and the Signal Corps lent their assistance.

During this time the Mycalex Corporation of America followed closely the developments at Norris. Mycalex had for many years been supplying the Nation with insulating products made of imported natural mica and high-quality electrical glass. Mycalex, like the Government agencies, was well aware of the need for developing a synthetic mica to replace the foreign product.

In March 1953 the Mycalex Corporation of America under a cooperative agreement with the Bureau of Mines actively entered the research and development work at Norris, Tenn. The result of this joint effort was the development of techniques for the commercial production of synthetic mica, a synthetic made of raw materials that are plentiful not only in the Western Hemisphere, but in the United States proper—aluminum oxide, magnesium oxide, silica sand, a fluoride, and potash feldspar. During the cooperative program, Mycalex produced, at its own expense, 200,000 pounds of synthetic mica.

One further point should be emphasized at this time. The word "synthetic" has come to have a negative connotation, implying "substitute." When we talk about synthetics, we think in terms of second best. This is not so with synthetic mica. Synthetic mica is actually a new engineering material—indeed, in many respects, a better material than the natural mica that must travel half way around the world before it becomes an integral part of our national defense.

Synthetic mica can be made chemically pure. We can actually give it many of the properties we desire. It can function effectively in temperatures several hundred degrees above the operating ranges of the natural product, making it the ideal insulating material against the high temperatures encountered by supersonic aircraft and missiles.

Because many types of mica can now be synthesized, and because it can be tailormade, it will now be possible to fill a prescription to the precise requirements of individual users, which is virtually impossible with natural mica.

Despite its obvious superiority to the natural product, synthetic mica is not yet the perfect insulator. Crystal size, for example, is not as large as it must be for all applications. Cost, too, is a factor. Both these problems, the first a technological, the second a production challenge, we expect to meet in the near future.

The turning point, however, has been passed. A new industry has been created, and the Nation is a long step closer to the self-sufficiency that spells survival. The world's first synthetic mica plant, the Synthetic Mica Corp., a wholly owned subsidiary of the Mycalex Corporation of America, is under construction. It is being built, not with Government funds, but with an initial capitalization of $500,000.

The United States has long been dependent on foreign sources for many critical materials, a situation which, in time of war, could be disastrous. Synthesis is one way to solve this problem. What the Mycalex Corporation of America has learned about synthesis is available to any industry, research group, or Government agency. The synthetic mica industry today is not only a reality but has actually opened up new vistas of electric, electronic, and nucleonic applications beyond the scope of the natural product it sought to replace. Our experience, we hope will be an added incentive to those already engaged in or about to embark on similar projects.

Appended is technical data relevant to the development and significance of synthetic mica, as compiled by the following members of the staff of the Mycalex Corporation of America:

H. M. Richardson, vice president, director, and senior engineering consultant. Formerly chief engineer, plastics division, General Electric Co. Since 1943 partner, firm of DeBell & Richardson, consultants to the entire plastics industry. Author of several authoritative texts in the plastics and related fields.

J. H. DuBois, vice president-engineering, and director. Supervises all engineering activities of the company. Past national president, Society of Plastics Engineers. Inventor, and author of textbooks on plastics, standard for colleges and universities throughout the world.

Richard A. Humphrey, chief-research and development. Identified with synthetic mica program from its inception; initially with Owens-Corning, and later in charge of the pilot-plant production of synthetic mica at the United States Bureau of Mines, Norris, Tenn., from 1947 to 1952.

Synthetic mica, as a new engineering material, opens up many avenues of research which already indicate they will provide materials that can solve several of the problems facing the Minerals, Materials, and Fuels Economic Subcommittee.

The mineral mica is a silicate of aluminum and potassium with hydroxyl, and sometimes fluorine, and usually with magnesium, iron, or lithium. Synthetic micas are true crystallographic analogs of the natural micas, wherein the hydroxyl ion, found in most natural micas, is replaced by fluorine.

Since the fluorine ion is more firmly bonded in the molecule, synthetic mica is more stable at elevated temperatures.

The raw materials used to synthesize fluor-phlogopite, the most common of the synthetic micas, are readily available in this country. The common glass-making materials constitute the majority of them. Silica (SiO_2), alumina (Al_2O_3), magnesia (MgO), and potash feldspar are in abundant supply while potassium silicofluoride (K_2SiF_6) is, fortunately, a byproduct of the phosphate fertilizer industry and, in almost chemically pure form, is also readily available.

The process to be used by the Synthetic Mica Corp., developed at the United States Bureau of Mines, Norris, Tenn., entails the electric melting of these materials in a furnace designed specifically for synthetic mica. Accurate proportioning of sufficiently pure materials is essential to the production of the high-purity fluor-phlogopite.

Synthetic mica has already proved its merit in glass-bonded mica; it holds real promise for the formulation of reconstituted sheet mica; Bureau of Mines developments indicate that synthetic mica can be hot-pressed and phosphate-bonded into some new mica ceramics. Let us consider each of these materials in more detail.

Glass-bonded synthetic mica.—A most significant form of mica insulation is a product composed of ground mica flakes bonded together with high quality electrical glass under high heat and pressure, resulting in a product known generically as glass-bonded inorganic insulation. The unique advantages of glass-bonded mica are its combination of outstanding properties: high heat endurance, permanent dimensional stability, radiation resistance, freedom from moisture absorption, moldability in intricate shapes to accurate dimensions and

fine surface finish, and ability to retain tightly anchored metal inserts under extreme vibration conditions, such as those obtained in military aircraft. Glass-bonded mica products have heat expansion properties similar to steel, so that no breakage results from expansion differences when used under wide temperature variations.

The substitution of synthetic fluor-phlogopite mica for natural mica in glass-bonded mica results in a general improvement of all properties due to the chemical purity, greater temperature stability, and the absence of hydroxyl ions in the mica molecules.

Heretofore, a serious limitation on the mechanical and fabrication properties of glass-bonded mica at high temperature has been the necessity of using a low melting point glass. Since a mixture of glass and natural mica will break down at high temperatures into a vitreous ceramic of mediocre electrical properties, the manufacture of glass-bonded mica products of the past has been limited to temperatures of 600° to 700° F.

The aircraft specifications of today demand insulating material that can be mounted on the jet engine afterburner and which will withstand continuous temperatures of 900° to 1200° F. These elevated temperatures can be met only by the use of Supramica 555 glass-bonded synthetic mica for complex molded products. The high temperatures resulting from flight at supersonic speeds require radomes with temperature stability above that to be gained by the use of glass-bonded natural mica.

Reconstituted sheet mica.—Fluor-phlogopite (synthetic mica) has one particular property not found in natural mica. Through the application of heat and/or pressure, it can be made to bond to itself. Taking advantage of this property, preliminary experiments indicate that several valuable basic materials are available to American industry.

The electrical and electronic industries are most familiar with mica as a sheet material. Using relatively small flakes of synthetic mica, it has been found possible to break up these flakes into small particles and lay them down into a sheet using a process similar to that for making paper. Subsequently this sheet, using no additional binder, has been heated under pressure to form a stiff sheet which promises to be a stock suitable for punching intricate, flat insulators.

The product development laboratory of Sylvania Electric Products, Inc., under a Bureau of Ships industry mobilization contract, has processed our synthetic mica into this sheet and subsequently punched experimental subminiature tube spacers from it. When installed in tubes, better life test results were achieved at elevated temperatures than was the case with the control lot of tubes made with natural mica.

With tube spacers as their primary goal, the Sylvania engineers have been forced to bypass other less rigorous applications for this sheet about which they are enthusiastic.

Hot-pressed and phosphate-bonded synthetic mica.—Researchers who have been associated with various synthetic mica projects are confident that several of the byproducts developed during these studies are suitable or superior substitutes for strategic block talc.

Again, using this peculiar bonding property of synthetic mica, one can make a hot-pressed machinable ceramic dielectric. Its main advantage over block talc is the fact that it is machined to final dimensions subsequent to any heat treatment; therefore, there is absolutely no shrinkage with which to contend. Standard tools are used for all machining, drilling, and threading operations.

It has been found also that powdered, sintered synthetic mica is an ideal material for the well-known phosphate-bonding method. That is, the synthetic mica powder is mixed with 5 to 10 percent phosphoric acid and cold-pressed by ordinary ceramic means. It can either be formed to final shape, allowing for the 2 percent firing shrinkage, or it can be fired in blocks and machined to final dimensions similar to hot-pressed synthetic mica. Both of these two materials have shown promise as an electromechanical support such as would be ued in electron power tubes.

RESEARCH AND DEVELOPMENT PLANS

In an effort to evaluate all of the potentialities of synthetic mica, the Synthetic Mica Corp. is going to operate an experimental furnace simultaneously with the production unit. This experimental unit will be kept in operation full time, not only toward the development of large, single crystals but also to take advantage of the many different synthetic micas available to us. In the Bureau of Mines

research on synthetic mica more than 100 different mica compounds have been made; each of these can have valuable properties which must be evaluated.

This type of furnace, developed originally for the crystallization of synthetic mica, should be ideal for the synthesis of many other refractory crystals, such as magnesium oxide (MgO), with its high infrared transparency.

In our pilot-plant runs, particularly when the size of melt was in the vicinity of 5 tons, we found some rather well-formed large mica crystals up to about 2 or 3 square in. area. We have reason to believe, extrapolating on our pilot plant experience, that by going to very much larger melts, our yield of large mica crystals will go up and the maximum size of crystal should also increase. Until we make much larger melts, say 10 ton, 20 ton, or even 40 ton melts, and provide for slow, undisturbed cooling, we will not know how much larger we can expect these maximum crystals to be, what the yield will be, and what it is likely to cost to isolate and split the crystals into usable mica sheet. We do know, however, that integrated or reconstituted mica sheet can be made by the process of Heymann of Integrated Mica Corp., and possibly by other processes.

Such integrated mica sheet and tape, when properly heat-treated, should provide a higher quality of product than is possible with natural mica, in that it should be suitable for somewhat higher temperatures, provided it is not necessary to use any organic binder in the structure.

The really critical material, of course, is large crystals of Ruby mica from India. It is these large uniform, clear crystals which are used as spacers in vacuum tube structures and as the dielectric in high voltage capacitors. They are also used in smaller sizes in the production of pasted mica for insulating tape and for commutator bar insulation and insulating cones on the commutators of d. c. motors and generators. It is for these large crystals that we hope and expect to provide a source of synthetic mica in our new synthetic mica plant. A higher yield of large crystals will not only replace a portion of the critical India mica, but will provide vacuum tube spacers of a much higher quality, allowing for the production of much more reliable and better vacuum tubes. Here the high temperature characteristics of our normal fluor-phlogopite mica will be of great advantage.

The ultimate economy in the production of synthetic mica will come from a well-balanced utilization of the product. The largest crystals will be saved for the very critical uses, the intermediate sizes for reconstituted mica, a large portion ground up to be used in glass-bonded mica, a portion of finely ground material to be used in phosphate-bonded mica, and the balance recycled in the process. For fullest utilization, we look forward to the use of synthetic mica in all of these applications.

It is clear to see, therefore, that a broad research and development program with this synthetic mica experimental and production unit at its heart can be of utmost importance to the accessibility of strategic and critical materials to the United States in time of war and for our expanding economy.

STATEMENT OF DR. CARY R. WAGNER, PRESIDENT, SYNTHETIC ORGANIC CHEMICAL MANUFACTURERS ASSOCIATION OF THE UNITED STATES

This statement is submitted in response to the invitation received from the subcommittee's counsel to inform the subcommittee of our views regarding the importance of research as it relates to "possible substitutes, replacements and the synthesis of critical materials."

Your subcommittee is familiar with the composition of this association, the importance of the organic chemical industry, which we represent, to national security, and the troublesome aspects of United States foreign economic policy which impinge on that status. These matters have, at the association's request, been laid before you in some detail by our general counsel in letters dated March 2 and 3, 1954. I shall not go over that ground in detail again, therefore, but incorporate those letters in this statement by reference.

These present hearings, I assume, are directed to the development of additional information relating to the following recommendation and finding contained in the subcommittee's report of June 23, 1954:

"11. We recommend appropriations of $50 million annually to establish and operate a comprehensive 5-year program of laboratory, pilot plant, and exploratory research into improved methods of beneficiation of critical materials and

the study of substitutes, including synthetics and replacements" (p. 4, subcommittee report).

"14. Laboratory research, pilot plant experimentation, and exploration is important in the interest of national defense and must be implemented—for new and improved methods of beneficiating critical materials and for new uses, substitutes, and replacements—and to facilitate the discovery of new reserves" (p. 9, subcommittee report).

The above recommendation and finding were made by the subcommittee with particular reference to critical minerals. This industry, of course, is not concerned with minerals as such. Synthetic organic chemicals have, however, served as substitutes for critical minerals, such as metals and rubber, in the recent past. For this reason, it is understandable that your subcommittee would be interested in the research activities of the synthetic organic chemical industry.

There is, moreover, an even larger ground for your interest. You are investigating the availability of critical materials (which includes more than just minerals) in time of war. Synthetic organic chemicals are critical materials in this sense, if by critical we contemplate all those materials which are essential to our defense mobilization obectives. A relative shortage of productive capacity for chemicals which are susceptible of being manufactured, or synthesized, from abundant raw materials is fully as critical to our defense potential as an absolute shortage of key minerals in the ground, or the nonexistence of adequate extractive facilities for key minerals which are in the ground, but inaccessible for want of those facilities.

We think that the same policy should be followed in meeting defense mobilization objectives in materials which can be manufactured, or synthesized, from abundant raw materials, as has been established for mineral stockpile objectives. As to the latter, your subcommittee report quotes President Eisenhower, as follows (p. 27, subcommittee report):

"1. It will be assumed, for the purpose of calculating long-term stockpile obectives, that, in the event of war, supplies will not be available from foreign sources except in the case of that limited group of countries to which wartime access can be had with the same degree of reliance as afforded by sources within our country."

That policy basis was reaffirmed by the Director of Defense Mobilization as recently as September 21, 1954, when he announced a revised purchase directive covering procurement of strategic materials for the stockpile during the 1955 fiscal year. He stated:

"The long-term stockpile program provides additional security and preparedness in the materials area. The objectives are calculated by discounting completely all wartime foreign sources of supply excepting a limited group of countries to which wartime access can be had with the same degree of reliance as afforded within the United States. The long-term program also provides for upgrading and refining of materials in order that they may be more readily useful in the event of emergency."[1]

A similar policy for manufactured materials would be consistent with the Director of Defense Mobilization's report to the President on October 1, 1953, stating that "our Nation must have a defense mobilization program of such magnitude and effectiveness as to either deter an aggressor or, if we should be attacked, to enable us to fight to win." The warning given by the National Security Training Commission in its report to the President on December 1, 1953, should be sufficient: "If there is another world war, we will not be granted the 2 years' grace we had in 1914 and 1939. The Kremlin would not repeat the error the Germans made twice in too recent history; we would probably be attacked first."

Let me then tell you of the synthetic organic chemical industry's research programs in relation to this twofold interest of providing substitute materials for critical materials, and in providing new and improved materials in the quantities required for defense needs.

As background information let me remind you that chemicals figure hugely in the economic life of the world, and in virtualy all productive operations: agricultural, pastoral, horticultural, construction, mining, and in all branches of manufacture.[2] The chemical industry enables farmers to increase soil fertility and protect cattle and plants from diseases and pests. It adds constantly to our

[1] Press release, OD–LS, September 21, 1954, No. 336.

[2] World Chemical Developments, 1940–46, pt. 2, p. 5 (U. S. Department of Commerce, 1948).

medical arsenal against disease and infection. One by one, it eliminates incurable diseases. Modern chemicals used by industry number in the thousands.[3] We are accustomed to think of the mechanization of industry as the awesome achievement of our age, but even more revolutionary has been the chemicalization of modern industry in recent decades.[4] Today in the United States, "practically every industry is dependent on the chemical industry to a considerable degree, and this is also true of every household and consumer." [5] There is scarcely a product of modern industry which does not at some stage of its manufacture require a chemical product.[6] Take automobiles. The automotive industry estimates that 256 different chemicals are used directly or indirectly in the production of automobiles. In 1953 that industry consumed organic chemicals valued at $590 million.[7]

This dependence of industry on chemicals is strikingly illustrated by the use of organic chemicals for war and essential civilian production in World War II and the Korean emergency. Total production of organic chemicals in 1939 was 4 billion pounds. At World War II's peak in 1944, the industry produced 15 billion pounds of organic chemicals, 92 percent of which were consumed in military or essential civilian uses. At the peak of the Korean emergency, in 1951, the industry produced 27.5 billion pounds of organic chemicals. In that limited emergency 41 percent of this massive production was of chemicals earmarked for essential defense production. But even this tremendous production, nearly seven times prewar capacity, and double World War II's peak, is not sufficient for defense mobilization needs in the event of an all-out emergency. Under certificates of necessity the industry is expanding its capacity to reach 36.5 billion pounds by 1956.[8] In 1953, our capacity was approximately 29 billion pounds.[9] You can see, therefore, that as of today 7.5 billion pounds of organic chemical productive capacity is critical, for if it is not provided, the Nation's mobilization base will be impaired by that amount.

This extensive dependence of the Nation's industrial-mobilization base on chemicals is documented in the files of the War Production Board pertaining to World War II. Thus, the Chairman of that Board wrote in 1944 that: "The chemicals required in the war effort are so far reaching and so fundamental that any loss of production at this time is bound to have a significant effect on a wide variety of vital programs." [10]

The Director of the War Production Board's Commodities Bureau wrote Maj. Gen. Lewis Hershey to the same effect in 1943:

"As you are probably aware, the continued production of an adequate volume of chemicals is a vital necessity to the entire war program. Chemicals are required, at one stage or another, in the production of all types of materials including ships, tanks, guns, airplanes, ammunition, medicinals, synthetic rubber, petroleum, mining, ore smelting and refining, agricultural production, and food processing. In fact, chemicals underlie the proper functioning of virtually every phase of the civilian and war economy. They are necessary and indispensable tools with which industry and agriculture produce their finished products." [11]

A total of 1,586 different organic chemicals were used directly or indirectly for explosives and other necessary materials by the Armed Forces during World War II. At least 100 others were developed and used in Korea.[12]

To form a proper understanding of our industry, its key importance to our national security, and the contribution which the industry's research can be expected to make to the alleviation of critical materials, we need to bear in mind a few more basic facts about the industry. This industry has come of age only since the First World War.[13] Since that time, it has made phenomenal progress

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[3] World Population and Production, Woytinsky, 20th Century Fund, New York, 1953, p. 1183.
[4] Ibid.
[5] Vol. II, report, President's Materials Policy Commission (1952), p. 103.
[6] Industrial and Engineering Chemistry, vol. 46, p. 1085 (June 1954).
[7] Allies in Defense, S. O. C. M. A., New York, 1954, p. 25.
[8] Trade, Strength, and Security, S. O. C. M. A., New York, 1953, pp. 19, 26, 38.
[9] See note 83, infra.
[10] Nelson, Donald M., letter, March 11, 1944, to Paul V. McNutt, Chairman, War Manpower Commission.
[11] Reid, E. W., letter, March 1, 1943, to Maj. Gen. Lewis Hershey, Director, Selective Service System.
[12] Allies in Defense, S. O. C. M. A., New York, 1954, p. 23.
[13] Vol. II, report, President's Materials Policy Commission (1952), p. 103; Trade, Strength, and Security, S. O. C. M. A., New York, 1953, p. 71; World Population and Production, Woytinsky, 20th Century Fund, New York, 1953, p. 1198.

by concentrating intensively on reasearch and development.[14] Technical brains are the most important raw material of the industry. Research is its lifeblood. Its birth, its existence, its development all depend on the painstaking work carried on in countess laboratories. From them in a continuing streamflow new products to relieve the strain on critical materials, and to make possible better, cheaper ways of providing America with food, clothing, transportation, health, housing, and the tools and equipment for work.[15] The greatest scientific activity in the past three decades has dealth with chemistry, and within that sphere, developments in organic chemicals have left the rest of the chemical industry in the shade.[16]

While the chemical industry as a whole is well ahead of other manufacturing in the United States, having tripled the volume of its output from 1929 to 1950 while the output of manufacturing as a whole only doubled,[17] the organic chemical industry has been increasing its growth at a rate approximately four times that of all industry.[18] The vigor of the synthetic organic chemical manufacturing industry is truly amazing. Comparing 1952 with 1939, production of synthetic organic chemicals increased 540 percent. This exceeds the increase over the same period of machinery production 2 times, all chemical products 3 times, all manufacturing 5 times, and manufactured food products 10 times.[19]

The production of dyestuffs is the foundation of the organic chemical industry.[20] As described by the Tariff Commission:

"Raw materials and basic technology of dye manufacture are common to the production of an almost endless variety of products indispensable to national defense and the public welfare. This technology has contributed to the vital progress made in such diverse fields as the production of synthetic drugs and medicinals; chemical warfare gases and smoke screens; synthetic rubbers, fibers, plastics, and resins; new and more powerful explosives; higher powered aviation fuels; synthetic camphor, insecticides, and insect repellents; and synthetic flavors and perfume materials. Products such as sulfa drugs, quinacrine hydrochloride [atebrin] * * *, and DDT * * * which were in large demand by the Armed Forces, could not have been made available without experience gained in the large-scale production and development of dyes.

"* * *. This convertibility has been the major reason for the high degree of tariff protection and other incentive measures afforded the dye industries of all the principal countries of the world." [21]

This adaptability of organic chemical manufacturing plants to the manufacture of a wide range of chemicals—from dyes to explosives; from intermediates to plastics; from flavors to medicinals; from resins to rocket fuels—is the key to the industry's vital role in peace and war. The technical literature of one of our members excellently reveals this interchangeability in its description of a new fine chemicals plant recently completed:

"[The] new fine chemicals plant is one of the most modern and versatile production units of its kind in the Nation. It was designed and built primarily to produce a broad family of dyestuffs, but is adaptable to the production of many other fine organic chemicals.

"The very complexity of dyestuff production was a major factor in [the] decision to begin * * * fine chemicals operations with the manufacture of dyes. It was felt that a modern well-designed plant would form a nucleus for the production of many fine chemicals, including surface active compounds, sequestering agents for the textile field, pharmaceutical intermediates and other fine chemical products.

"Because of the diversity of operations involved in producing dyestuffs, the fine chemicals plant is designed to carry out practically all types of organic chemical reactions. * * * ." [22]

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[14] Vol. II, report, President's Materials Policy Commission (1952), p. 103.
[15] World Population and Production, Woytinsky, 20th Century Fund, New York, 1953, p. 1180.
[16] Vol. I, report, President's Materials Policy Commission (1952), p. 142.
[17] World Population and Production, Woytinsky, 20th Century Fund, New York, 1953, p. 1183.
[18] Vol. IV, report, President's Materials Policy Commission (1952), p. 191.
[19] Upgren and Sargent, Economic Analysis of Synthetic Organic Chemical Industry, Hanover, N. H., 1954 (MS), p. 13.
[20] World Population and Production, Woytinsky, 20th Century Fund, New York, 1953, pp. 1196–1197.
[21] U. S. Tariff Commission, War Changes in Industry Series, Report No. 19, p. 69.
[22] Pittsburgh Dyestuffs, Pittsburgh Coke & Chemical Co., Pittsburgh, Pa., 1953, p. 6, 7.

We have then an industry whose plants and facilities are quickly adaptable to the manufacture of all types of a vast host of organic chemicals which industry needs in peace or war. More than 7,000 organic chemicals are now made commercially. More than half a million organic compounds have been developed in the laboratory, or described in technical literature.[23]

The research effort which has been responsible for the rapid growth of the industry and, in large part, for the chemicalization of all manufacturing activity in the United States is staggering. In 1921, we spent $4,247,000 on reasearch; the aggregate effort of 68 companies.[24] In 1953, our industry spent $218 million on research; the sum total of the efforts of 363 companies.[25] In 15 years, 1938–52, our industry's research expenditures grossed $1,043.2 million.[26] In the four-year period, 1953–56, our companies will match that with another billion dollars spent on research. The industry's research budget exceeds 5 cents out of each dollar of sales; a record which is unmatched by any industry using its own funds for reasearch.[27]

Some perspective can be gained by contrasting this research record, and that of the chemical industry as a whole, with other industries.

In 1951, the most recent year for which such data are available, the chemical industry topped every other industry in the amount of research performed with its own funds:

Research performed with own funds [1]

	Percent	Amount
Chemicals [2]	92.9	$190,000,000
Electrical machinery	43.	186,000,000
Aircraft	14.9	61,000,000

[1] Upgren and Sargent, Economic Analysis of Synthetic Organic Chemical Industry, Hanover, N. H. 1954 (MS) p. 113; Trade, Strength & Security, SOCMA, New York, 1953, pp. 121, 122.

[2] 74 percent of total chemical industry research expenditures of $204 million in 1951 were in the synthetic organic chemical segment of the industry. Upgren & Sargent, op. cit., supra, note 28, at pp. 116, 117.

This is not to suggest, however, that the industry's research was not important to national defense. In fact, the industry performed some of the research work required by the Federal Government without reimbursement, participating in defense research to a larger extent than the percentage cited would indicate.[28]

Importantly, over 55 percent of the chemical industry's research is devoted to the development of new products, and another 12 percent to basic research.[29] Only the primary metals industry devotes more to new product research, and only the food industry puts a greater portion of its research effort into basic research.[30] These figures reflect the conviction of the chemical industry that its best opportunities lie in the development of new products and processes. It spends only 30 percent of its research funds in the protection of the status quo, the lowest of any major industry group. The majority of these industries (rubber, paper products, fabricated metals, petroleum products, electrical machinery, and instruments) devote over half of their research expenditures to the improvement of present products rather than the creation of new products or basic research.[31]

Significantly, too, the nonprofit institutions performing research receive their greatest support from the chemical industry.[32] The chemical industry employs

[23] World Population and Production, Woytinsky, 20th Century Fund, New York, 1953, p. 1204.

[24] Trade, Strength, and Security, S. O. C. M. A., New York, 1953, p. 97.

[25] U. S. Tariff Commission, Synthetic Organic Chemicals, United States Production and Sales, 1953, Report No. 194 (2d series), p. 169.

[26] Trade, Strength, and Security, S. O. C. M. A., New York, 1953, p. 121.

[27] Electrical machinery, aircraft, and parts, and scientific instruments had higher percentages in 1951, but in each case more than half of total research costs was paid by the Federal Government, rather than industry funds. In that year, less than 10 percent of the organic chemical industry's research costs came from Federal funds. Upgren and Sargent, Economic Analysis of Synthetic Organic Chemical Industry, Hanover, N. H., 1954 (MS), p. 116.

[28] The Growth of Scientific Research and Development, Department of Defense, Washington, D. C., 1953, p. 2; Scientific Research and Development in American Industry, Bureau of Labor Statistics, Washington, D. C., 1953, p. 23.

[29] Chemical Engineering, vol. 61, p. 331 (July 1954).

[30] Turner, How Much Should a Company Spend on Research, Harvard Business Review, vol. 32, p. 108 (May–June 1954).

[31] Ibid.

[32] Ibid., p. 110.

twice as many research engineers and scientists on private research as any of the other major industries.[33] In the 12-year period 1941–52, the synthetic organic chemical industry quadrupled its employment of research workers, from 2,957 to 12,203. The salaries paid to its research workers increased more than eightfold in the same period, from $8,966,000 to $76,701,000.[34]

A similar indication of the impact of the organic chemical industry's research program can be secured from an anlysis of the growth in numbers in the chemical profession, and the types of activity in which its members engage. A recent study of the Bureau of Labor Statistics is eloquent on this point:

"The giant chemical industries built up in this country since World War I were made possible by the discoveries of chemists, who benefited in turn from the resulting employment opportunities. The profession is so closely associated with industry that the relative numbers of chemists in different specialties reflect, to a considerable extent, the degree of emphasis on each specialty in industrial research and development programs.

"Most industrial applications of the science are in organic chemistry. Consequently, many more chemists specialize in this than in any other branch of the profession. * * *"[35]

The study points out that the principal activity of chemists, 67 percent of whom work in manufacturing industries, is research, and that more than half of all chemists in manufacturing are employed by the industrial organic and inorganic chemicals segment of the chemical and allied products industrial group.[36] An even greater proportion of the Nation's chemical engineers, 87 percent, are employed in manufacturing, though here less than half were in the chemical industry.[37] The proportion of all chemists in manufacturing who were employed by the chemical industry increased from 44 percent in 1941 to 53 percent in 1951.[38] Among chemists in the manufacturing industries, as in the entire profession, the organic chemists were by far the largest group.[39] Nearly three-fifths of the chemists in the chemical industries were in the organic field.[40] In 1952 the organic and inorganic sectors of the chemical industry employed 40,000 chemists and engineers, assisted by 18,000 technicians. Nearly 75 percent of these are employed in the organic chemical sector of the industry. In all, more than 100,000 chemists and 50,000 engineers staff the plants and laboratories of the Nation—double the number in 1940.[41]

The exceptional research efforts of the chemical industry have kept the industry in the white heat of expansion, calling annually for extraordinary investment in new plant and equipment. The Survey of Current Business very recently presented an analysis of the chemical industry as illustrative of the growth characteristics of the American economy. Of research and its impact on plant and equipment expenditures, the survey commented:[42]

"The expansion of the chemical industry has in large measure resulted from an ever increasing scale of research and developmental work over the past decades. * * *.

"The chemical industry's expenditures for new plant and equipment have kept pace with the expanding outlays for research and development of new products. This investment has been at a very high rate throughout the postwar period and particularly since 1950, when the defense program necessitated the immediate installation of greatly expanded production capacity of chemicals.

"Despite the tremendous new capacity built during World War II the expanding peacetime markets for chemical products in postwar years required additional substantial investments in new plants and facilities. From 1946 through 1953, outlays for new plant and equipment by the chemical industry averaged close to $1.1 billion annually, aggregating $8.5 billion over the 8-year period and representing 10 percent of the total for all manufacturing. * * *"

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[33] Trade, Strength, and Security, SOCMA, New York, 1953, p. 122. As of January 1, 1952, the chemical industry so employed 13,264 research engineers and scientists. The next closest industry was electrical machinery, with 6,915 so employed.
[34] Upgren and Sargent, Economic Analysis of Synthetic Organic Chemical Industry, Hanover, N. H., 1954 (MS), pp. 113, 114.
[35] Manpower Resources in Chemistry and Chemical Engineering, Bureau of Labor Statistics, Washington, D. C., 1953, p. 13.
[36] Ibid., p. 4.
[37] Ibid., pp. 7, 8.
[38] Ibid., p. 23.
[39] Ibid.
[40] Ibid., p. 24.
[41] Ibid. (Derived.)
[42] Growth Characteristics of the Economy, Survey of Current Business, vol. 34, September, 1954, p. 14.

In 1953, chemical companies devoted 70 percent of their capital spending to capacity expansion, compared to 48 percent for all manufacturing.[43] Manufacturing industry plans to increase its productive capacity only 4 percent in 1954 and by an added 9 percent in 1957. The chemical industry will step up its expenditures for expansion to increase productive capacity 7 percent in 1954, and add another 22 percent by 1957.[44] Half of the total investment and three-fourths of the total expenditures for expansion by chemical manufacturing companies is for new products.[45] The results are dramatically apparent, for over 40 percent of the industry's sales, and its profits, now come from products which did not exist 15 years ago.[46] New chemicals make their commercial debut at the average rate of one for every working day of the year.[47]

It is this very characteristic of constantly pushing back the frontier of industrial chemistry through exceptional research and development expenditures which merits the attention of your subcommittee. For your concern that substitutes be provided for scarce minerals, metals, and other materials through the development of synthetics and replacements by new and better materials is a familiar blueprint for this industry. The most notable supplements to our national materials stream in recent years have been the array of new synthetic organic chemicals—highly versatile plastics, artificial fibers and pharmaceuticals, synthetic rubber, and the like.[48] The industry's record in the past gives a sound basis for expecting new synthetics of its manufacture to relieve some of the Nation's most serious materials difficulties in the future.[49] The promise of organic chemical technology is great. We work with the most plentiful of materials as our raw materials—air, water, coal, natural gas, petroleum, molasses, oat hulls, brine. We have demonstrated almost unlimited capacity to rearrange their molecular structure, use the materials interchangeably, and mass-produce intricate synthetic compounds to the most exacting specifications to do essential jobs cheaper, better, stronger. Dyestuffs, medicinals, synthetic rubber, plastics, camphor, synthetic fibers, detergents, antibiotics, agricultural chemicals—these are some of the many examples.[50] Permit me to discuss just a few of them briefly.

Before World War II, the United States was dependent on distant foreign sources for virtually its entire new rubber supply.[51] In 1941, the Nation secured a new rubber supply of 1,312,000 long tons of rubber and latex, of which only 8,000 long tons was synthetic. The war cut our supply lines to Southeast Asia, and at the same time vastly multiplied our urgent needs for rubber. Organic chemical research was equal to the occasion. The Federal Government threw up synthetic rubber plants in a crash operation. Our industry supplied the technology, the manpower, the chemical intermediates. In 1944, we procured a new supply of 1,142,000 long tons of rubber, 774,000 tons of which was synthetic rubber produced in this country.[52] In 1945, we produced 820,000 long tons of synthetic rubber.[53] Our dependence on foreign sources for rubber was a thing of the past.

Equally dramatic is the way in which synthetic organic plastics materials stepped into war harness. The great variety of properties obtainable in the different plastics gave them utility in nearly every segment of industry.[54] Plastics substantially supplemented the supply of copper, zinc, lead, tin, steel, glass, leather, ceramics, rubber, and wood.[55] Production of synthetic plastic materials reached 782 million pounds by 1944, three and a half times 1939's production.[56] If it had not been for the development of plastic and resin materials technology to supply effective substitutes, there would have been a critical military equipment problem in World War II resulting from the curtailment of rubber and metal supplies.[57]

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[43] Chemical Engineering, vol. 61 (May 1954), p. 344.
[44] Chemical Week, April 17, 1954, p. 28.
[45] Growth Characteristics of the Economy, Survey of Current Business, vol. 34, September 1954, p. 14.
[46] Annual Report, 1952, Chemical Fund; Standard & Poor's Current Analysis of Chemicals (January 7, 1954); cf. Annual Report, Monsanto Chemical Co., 1953, p. 21.
[47] From the Salt of the Earth, Hooker Electrochemical Co., Niagara Falls, N. Y., 1951, p. 14; cf. Allies in Defense, S. O. C. M. A., New York, 1954, p. 19.
[48] Vol. I, report, President's Materials Policy Commission (1952), p. 10.
[49] Ibid.
[50] Vol. II, report, President's Materials Policy Commission (1952), p. 103.
[51] Ibid., p. 100.
[52] Trade, Strength, and Security, S. O. C. M. A., New York, 1953, p. 28.
[53] Vol. II, report, President's Materials Policy Commission (1952), p. 100.
[54] Ibid., p. 105.
[55] Ibid.
[56] Trade, Strength, and Security, S. O. C. M. A., New York, 1953, p. 35.
[57] Press release, J. W. Ravnolds, Deputy Director, Chemicals Bureau, War Production Board, February 18, 1944, Chemicals and the Synthetic Resin Industry.

Many other great wartime industrial programs to supply World War II's military needs came directly from the research laboratories of the synthetic organic chemical industry: sulfa drugs, penicillin, vitamins, disinfectants, insecticides, mildew inhibitors, antifreeze for military vehicles, high-octane aviation gasoline, de-icer fluids, brake fluids, solvents, self-sealing gas tanks, plastic coatings for electronic systems, rocket fuels, and various types of explosives, including smokeless powder, primers, and detonators.[58] To this list, the industry added in the Korean emergency bulletproof vests, rockets, napalm bombs, jet fuels, and new wonder drugs, streptomycin, and synthetic vitamins.

From the beginning, the chemical industry supplied technology and personnel to the development of the atomic bomb,[59] and, later, of peaceful uses for atomic energy. Members of our industry operated the Clinton National Laboratories at Oak Ridge; the Mound Laboratory at Miamisburg, Ohio; supplied technical men for use as key personnel in the atomic energy project at Rocky Flats; transferred nearly a hundred Ph. D.'s and over a thousand technically trained or other key employees to the Atomic Energy Commission; put 20 scientists to work on a process for making one of the important chemicals needed in the atomic energy program; and operated the Oak Ridge plant of the Atomic Energy Commission.[60] Between 1950 and 1953, about 20,000 chemical company workers were employed at 8 AEC installations. At the present time, nearly 4,000 chemists and chemical engineers are employed in AEC projects.[61]

The development of synthetic organic insecticides, fungicides, herbicides, seed disinfectants, and fertilizer chemicals is a very recent occurrence which will multiply our food supply. More than 4,000 chemical formulations for the control of insects and plant diseases contribute to farm productivity. Special organic medicinals, pesticides, and chemically fortified feeds improve and increase the food yield from cattle, hogs, and poultry.[62] All contribute to the alleviation of shortages in the food supply in times of emergency when huge military requirements are suddenly superimposed on the steadily increasing needs of the civilian populace.

The meteoric rise of detergents, whose active ingredients are synthetic organic surface active agents, has in less than 10 years eclipsed the soap market, reducing the Nation's dependence on imported oils and fats. Production of synthetic detergents increased from 30 million pounds in 1940 to 2,134 million pounds in 1953. Soap production over the same period declined from a little over 4 billion pounds to just under 2 billion pounds.[63] Through the technology of the organic chemical industry, another troublesome material problem—one which seriously inconvenienced the civilian populace in World War II—has been eliminated.

The significant fact from your subcommittee's point of view is that this process of developing new products which take the place of old, ofttimes critical materials, is a continuing one with the industry, ever increasing in its intensity. An illustration of what can be expected in the immediate future is at hand in but a brief perusal of the annual reports of our companies. A few will suffice.

One company reports increased emphasis on exploratory research. It is operating 59 pilot-plant projects, 21 of which are aimed at process improvements, while 27 are concerned with products new to the company, and 11 with products new to the industry. This company is carrying on research in the application of radioactive materials to analysis and chemical reactions. It is studying the development of commercial atomic power.[64]

Another company is carrying on research in an entirely new field of chemical synthesis, the preparation of organic fluorocarbons and chlorofluorocarbons. This is in pilot-plant stage. The company expects this field of research to yield superfast dyes, longer-lived lubricants, better solvents, better plastics, dielectric fluids, drugs and insect killers, and new chemical intermediates. This company is conducting a major research program with the Atomic Energy Commission,

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[58] Trade, Strength, and Security, S. O. C. M. A., New York, 1953, pp. 32–36.
[59] Memorandum, D. P. Morgan, Director, Chemicals Bureau, War Production Board, to Donald Nelson, Chairman, War Production Board, February 2, 1944: "There is a large secret project of the Corps of Engineers which is considered of such urgency that the sponsoring agency has been authorized to issue AAA ratings in the field. It is understood that this project involves several hundred million dollars of new construction and will have to be staffed by drawing upon existing skilled personnel in the chemicals industry."
[60] Trade, Strength, and Security, S. O. C. M. A., New York, 1953, p. 115.
[61] Allies in Defense, S. O. C. M. A., New York, 1954, p. 23.
[62] Ibid., p. 27.
[63] Growth Characteristics of the Economy, Survey of Current Business, vol. 34, September 1954, pp. 12, 13.
[64] Annual Report, 1954 Fiscal Year, Dow Chemical Co., p. 11.

and plans are underway for the construction and operation of a plant for the Commission. The company developed a new fire- and heat-resistant polyester resin in 1953, useful in fiber-plastic auto bodies and parts, panels for architectural uses, glass fiber-polyester pipe, and chemical tanks.[65]

A third company is carrying out a major research and development program on a new chemical, hydrazine, which shows promise as a rocket fuel and as a starting point for a new family of chemical compounds, the hydronitrogens.[66]

Another company has developed new types of polyethylene plastics possessing greater resistance to heat and to water vapor penetration, and remarkable strength, toughness, and flexibility. This company is in the pilot-plant stage on a new liquid polybutadiene for use in adhesives, resin plasticizers, and other applications. It has been selected by the Atomic Energy Commission to manage certain activities at the National Reactor Testing Station near Arco, Idaho. This is in addition to the company's present operation of the materials testing reactor. It also operates the Idaho Chemical Processing Plant, the function of which is to recover fissionable uranium from used reactor fuel elements. The company has developed and is producing solid fuels for jet-assist takeoff rockets for the Air Force.[67]

It must be rather apparent to you by now that the synthetic organic chemical manufacturing industry is a factor of major importance in the development of substitutes for critical materials through new synthetic products. It would be difficult for the Federal Government to duplicate the immense research effort being carried out in the laboratories of some 363 companies at a current annual cost of $218 million.[68] The dramatic, vigorous, step-by-step unfolding of the industry's research and development program, and the hand-in-hand expansion of plant and equipment to produce commercially the new chemicals developed in its laboratories is a national security asset of incalculable value. No less than the new synthetics which emerge from that process to relieve pressure on critical materials, the accompanying expansion in total organic chemical manufacturing capacity through billion dollar a year new plant and equipment expenditures deserves attention as a defense asset of enormous importance. For the latter, if unimpeded, will bridge the gap now existing between present capacity and total defense mobilization requirements.

Need I remind you that there was a time when America was forced to fight a war without an organic chemical industry, and chaos and disaster were skirted narrowly with the help of the Altantic and 3 years in which to prepare.[69] Today's supersonic aircraft have shrunk the world into narrow compass. The lead time to prepare for national defense when war threatens has been compressed into hours. The products of our industry are vitally needed in peace and in war by all the major industries in the United States. They are indispensable to our national security. What is more, the capacity and activity of our industry as a vigorous going concern with its dominant characteristics of extraordinary annual research and expansion expenditures are a priceless heritage given by a wise and farseeing tariff policy to the safety and well-being of all our citizens. There is no other industry in the United States for whom the Congress and the Executive strove in such patient and singleminded determination to fortify from vicious foreign competition as the organic chemical industry. The tariff policy embodied in the Tariff Act of 1922 was proposed by a wartime Democratic President, and enacted by a peacetime Republican Congress. It was reaffirmed without change in the Tariff Act of 1930. The purposes of the rates and provisions contained in the chemical schedule of those acts are clearly revealed by the legislative history:

(1) To safeguard the national defense through chemical technology and productive capacity for explosives, medicinals, dyestuffs and the other industrial chemicals required in wartime;

(2) To advance medical chemistry and strengthen the health resources of the Nation;

(3) To stimulate national economic growth and prosperity through continued expansion of the chemical industry, and the establishment of new industries based on products of organic chemical research;

(4) To provide an adequate reservoir of skilled chemists and chemical engineers to serve industry in peace and the Nation in war;

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[65] Annual Report, 1953, Hooker Electrochemical Co., pp. 8, 22.
[66] Annual Report, 1953, Mathieson Chemical Corp., p. 9.
[67] Annual Report, 1953, Phillips Petroleum Co., p. 20.
[68] See note 25, supra.
[69] See ch. III: Trade, Strength, and Security, SOCMA, New York, 1953.

(5) To encourage scientific research and multiply chemical laboratories throughout the Nation to provide employment for students attracted to the chemical profession;

(6) To protect the American organic chemical industry from the economic warfare of foreign cartels."[70]

I think you will agree with me that the organic chemical industry has measured up to the responsibilities imposed on it by this beneficent tariff policy, in achieving each of the above objectives in outstanding fashion.

Our industry is becoming greatly concerned over the substantial retreat which has recently been made from that tariff policy under the trade agreements program: 90 of the 116 tariff rates applying to synthetic organic chemicals have been reduced by trade agreement concessions.[71]

In 1952, 96 percent of all chemical imports were subject to reduced rates of duty.[72] The average ad valorem equivalent of United States chemical tariffs stood at 25.1 percent before trade-agreement cuts were commenced.[73] As of January 1, 1953, trade-agreement concessions had reduced the average ad valorem equivalent of chemical duties by 51 percent, to 12.4 percent.[74] As of January 1, 1954, the average equivalent of chemical ad valorem rates stood at 11.6 percent, while overall, for ad valorem, combination, and specific duties, it was 13.4 percent, reflecting the decline in unit value of chemical imports subject to specific duties in 1953.[75] These tariff reductions have been made without regard to the effect of increased organic chemical imports on the projected defense mobilization capacity expected of the industry.

For the most part, World War II, its aftermath of reconstruction, and the inflationary effects of the Korean emergency have prevented until recently an appraisal of the effects of these tariff reductions on United States imports of synthetic organic chemicals. But as some semblance of normality returns to international economic relations, it is becoming increasingly evident that the State Department negotiators have cut too deep on organic chemical tariffs. Imports of organic chemicals, beginning with 1949, the first year of substantially normal industrial activity in Europe, have increased from $18 million to $50.6 million in 1953. United States exports of organic chemicals have declined in that period from $308 million to an estimated $302 million in 1953. In the industry's basic category of dyestuffs, United States exports have declined from $78 million in 1947 to $14 million in 1952, rather clearly indicating the loss of third markets to our foreign competition. Imports of dyes in the same period increased from $2 million in 1947 to $6 million in 1953.[76]

The organic chemical industry has sustained a disturbing loss in employment since 1953. The number of production workers in the industrial organic chemicals segment of the chemical and allied products industrial classification has dropped each month. From 229,000 in August 1953, employment declined to 201,000 in June of 1954. This is a loss of 28,000 workers, or roughly 12 percent. It exceeds the decline percentagewise during the same period in employment of production workers in the all manufacturing group (11.2 percent), and the nondurable goods industries (9.7 percent), and chemicals and allied products (5.8 percent) groups of which it is a part."[77]

This abnormal decline in employment has been experienced at a time when many of our companies have idle plant capacity and imports of organic chemicals in important basic categories of our domestic production have shot up. Intermediates zoomed from 3.7 million pounds in 1952 to 25.4 million pounds in 1953. Lakes and toners, from 5,000 pounds in 1952 to 280,000 pounds in 1953. Dyes (computed weights adjusted to Treasury Department standards of strength) imported increased from 2.7 million pounds to 3.3 million pounds. Medicinals, from 960,000 to 1.4 million pounds. Plastics and resins from 4.9 to 9.5 million pounds. Surface active agents from 530,000 to 900,000 pounds. There was a sharp decline in imports of Canadian elastomers from 44.5 million pounds in 1952 to 28.6 million

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[70] Ibid., pp. 95, 96.
[71] Trade, Strength, and Security, SOCMA, New York, 1953, p. 198.
[72] U. S. Tariff Commission, Effect of Trade Agreement Concessions on United States Tariff Levels Based on Imports in 1952, Washington, D. C., 1953, p. 11.
[73] Ibid., p. 12.
[74] Ibid.
[75] Unpublished Bureau of Customs data.
[76] Statistics for all years through 1952 are taken from Trade, Strength, and Security, SOCMA, New York, 1953, pp. 157, 178; 1953 data, Bureau of Census, Foreign Trade Report No. 9011, August 1954.
[77] Survey of Current Business, U. S. Department of Commerce, vol. 34, September 1954, p. S–11.

pounds in 1953, due chiefly, I believe, to the low price of natural rubber in 1953 and the removal of certain Government mixing regulations in 1953 which tended in 1952 to result in imports. This rather large decline in elastomers imports in 1953 gives even more significance to the increase of synthetic organic chemical imports of all kinds from 115.6 million pounds in 1952 to 132.9 million pounds in 1953.[78]

We think that recent bipartisan legislation gives the key to the correction of a disturbing situation of this sort. The so-called Symington amendment to the Trade Agreements Extension Act of 1954[79] provides that no action shall be taken under the trade-agreement authority to decrease the duty on any article if the President finds that the reduction would threaten domestic production needed for projected national defense requirements. The theory and purpose of this amendment is to protect defense mobilization capacity from import injury. This is certainly an objective in harmony with the findings of your subcommittee. Though no mention is made in the act of the withdrawal of concessions which have resulted in imports which threaten defense mobilization capacity, such action is quite consistent with, if indeed it is not required by, the spirit of the act. It is obviously just as important to remove tariff concessions which are impairing our defense mobilization capacity as it is to avoid making concessions which would have that effect. The escape clause is not a sufficient remedy, because productive capacity essential for projected national defense requirements (which may include expansion of existing capacity) may be impaired long before the domestic industry concerned actually sustains serious injury within the meaning of the escape clause. As an example, consider the situation of the organic chemical industry. Capacity under certificates of necessity is to be expanded by 1956 to some 36.5 billion pounds annually.[80] Present capacity is in the neighborhood of 29 billion pounds.[81] Increased imports could make it economically inadvisable for the industry to continue the rate of expansion required to yield the required defense mobilization capacity, yet it would not necessarily follow that the industry would have sustained serious injury within the meaning of the escape clause.

We advocate that regardless of what form our national foreign economic policy takes, it by all means include adequate, efficient, speedy procedures to safeguard essential defense mobilization productive capacity, whether in being, or projected via expansion of existing facilities, from import injury.

This industry has recommended such a procedure which essentially would forbid further tariff cuts and require withdrawal of existing concessions on items as to which the Tariff Commission finds that increased imports threaten productive capacity declared by the Office of Defense Mobilization to be a part of the Nation's total mobilization base.[82] The procedure is summarized at pages 8 to 10 of our General Counsel's letter to the chairman, dated March 2, 1954. It is described in more detail in our study, Trade, Strength, and Security, at pages 203 to 209.

We appreciate the opportunity of bringing to your attention the facts which make the synthetic organic chemical manufacturing industry of exceptional importance to the problem which you are considering—that of relieving critical materials problems through the development of synthetics through research to replace or supplement them. We hope that this statement will assist you in understanding the concern we have over the steadily increasing imports of foreign chemicals which could blunt the magnificent contributions which our industry is making to the strength of the domestic economy and our industrial resources for national defense through its exceptional rate of growth, its extraordinary research expenditures, and its billion dollar a year investment in new plant and equipment. We hope too that our suggestions regarding a procedure to safeguard our industrial defense assets will be of interest to you in your search for solutions to the critical materials problems of America.

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[78] Statistics for 1952 are from Trade, Strength, and Security, SOCMA, New York, 1953, p. 156; 1953 data, Bureau of Census, Foreign Trade Report No. 9011, August 1954.

[79] Sec. 2, Public Law 464, 83d Cong. (2d sess.), 68 Stat. 360.

[80] Trade, Strength, and Security, SOCMA, New York, 1953, p. 26.

[81] Based on total United States production of finished synthetic organic chemicals as reported for 1953 in U. S. Tariff Commission, Synthetic Organic Chemicals, United States Production and Sales, 1953, Report No. 194, 2d series, p. vii. Though the industry had some idle capacity, the 29 billion pound figure, according to the Commission, includes "much duplication." Ibid., p. vii.

[82] Trade, Strength, and Security, SOCMA, New York, 1953, pp. 203–209.

ALLIES IN DEFENSE—SOME FACTS ABOUT SYNTHETIC ORGANIC CHEMICALS, 1954

Published by Synthetic Organic Chemical
Manufacturers Association, New York, N. Y.

(Much of the material contained herein is based on the publication Trade, Strength, and Security, which was prepared for the Commission on Foreign Economic Policy. Address request for a copy to Synthetic Organic Chemical Manufacturers Association, 41 East 42d Street, New York 17, N. Y.)

> "The chemical industry today must be reckoned among the greatest industrial forces of all time—it is the nerve center of our entire industrial system. In peacetime its products are essential to every phase of our daily lives; in wartime they are indispensable."
>
> —Maj. Gen. E. F. BULLENE, U. S. ARMY.

I. PREFACE

America is indeed fortunate in having a vigorous, dynamic chemical industry. Encouraged as a part of national policy by sufficient tariffs against unfair competition from low-labor-cost producers abroad, the organic chemical industry has enjoyed the climate necessary to promote reinvestment of profits in research. This support has made possible the great achievements of the industry in the past and has built the base on which ever greater contributions to our national welfare will be possible in the future.

The phenomenal growth of the organic chemical industry has had and continues to have a profound effect upon the United States economy. Since its beginning in this country less than 40 years ago, the industry has:

Grown at a rate four times faster than the average of all United States industry;

Spent more money for research, per sales dollar, than any other industry;

Invested $9 billion in new plants and equipment during the past 9 years;

Increased the value of its products from $384 million in 1939 to a current $3,800 million;

Become a major supplier of products essential to the health, progress, and national security of America.

While the chemical industry is one of the youngest of our great industries, chemical processes have benefited mankind since the dawn of history. Some historians consider Egypt the birthplace of chemistry, for it was there 40 centuries ago that the first glass was made. The Egyptians melted sand with soda to extract gold and discovered that the soda caused the melted sand to fuse into glass. In Alexandria, alchemists applied soda to soap and dyemaking, and used it as a medicine. The ancients also knew how to turn wine into vinegar and to use acids for metal treatment.

But these were largely unscientific crafts, based on chance discoveries and, although widely used, little understood. Chemistry for centuries was viewed more as a form of magic than a science and the early alchemists often perverted its use to ignoble ends.

The end of the 18th century saw the birth of the science of chemistry when the great discoveries of Dalton, Priestly, Berzelius, Scheele, and Lavoisier gave man more knowledge of the components of the physical world and suggested the possibilities of creating new substances by chemical reaction. Since then the science of chemistry has moved forward at an increasing pace, proving itself one of man's most valuable tools in the control of his environment.

Great progress has been made in the field of organic chemistry and the industry that supplies organic chemical products is becoming increasingly important in our everyday lives. Few chemical compounds are end products in themselves so that few people are aware of the many important roles chemicals play in the modern industrial and consumer products that support our high standard of living. While the importance of synthetic organic chemicals to national defense is widely recognized, this subject still deserves special attention. In these times, total war is an ever present possibility and every chemical facility must be considered a defense asset.

As a result of national policy, this country today enjoys technological advantages in matters of chemistry—one of the most powerful deterrents to any aggressor and at the same time a powerful force for assuring an advancing standard of living. By new and improved products and processes, chemistry works

to furnish more for less and moves steadily toward creating abundance—one of the surest ways to remove the historical causes of unrest, tension, and war.

II. Beginnings of the Industry

The synthetic organic chemical industry deals with the compounds of carbon, obtained from coal, petroleum, natural gas or agricultural products, whichever is most convenient, and through synthesis and other techniques of modern chemistry, creates new substances in potentially greater variety even than is provided by nature.

Starting with a few building blocks called intermediates, the industry fashions thousands of different products that contribute to the health, security, comfort and convenience of mankind.

The true beginning of the synthetic organic chemical industry dates from 1856 when the first manmade dye was developed in England by William Perkin. His discovery of the first aniline dye was the initial step in using science to create completely new substances—the counterparts of natural products. A generation of intense activity in scientific analyses had preceded this chance discovery.

Starting about the time of the French Revolution, with the encouragement of Napoleon and other political figures who patronized scientists working in their laboratories, very rapid progress was made in determining the chemical structure of hundreds of plant and animal products. What the scientists were seeking was to discover the details of natural chemical processes so that they might make useful substances which nature only grudgingly provided. It is the same ambition that is the driving force in chemical research today.

Chemicals are frequently spoken of as "organic" or "inorganic." Of all the hundred know elements, carbon forms the most compounds. For a long time it was believed that only those natural plant and animal products—in other words, products derived from things that were alive or had lived—were organic (containing carbon). All other materials—those that had never lived, such as salt, rocks, sand and other minerals, water and most gases—were classed as inorganic or nonliving.

While the early scientists were amazed at the number of compounds containing carbon that they found in analyzing plant and animal tissue, this fact is explained by the unique ability of carbon to link up with itself and other chemical elements, such as hydrogen, nitrogen, oxygen, etc., to form more chains or rings than any other element. Starches, sugars, oils, fats, and proteins of hundreds of different kinds—all contain carbon—are therefore organic.

ABOUT SYNTHESIS

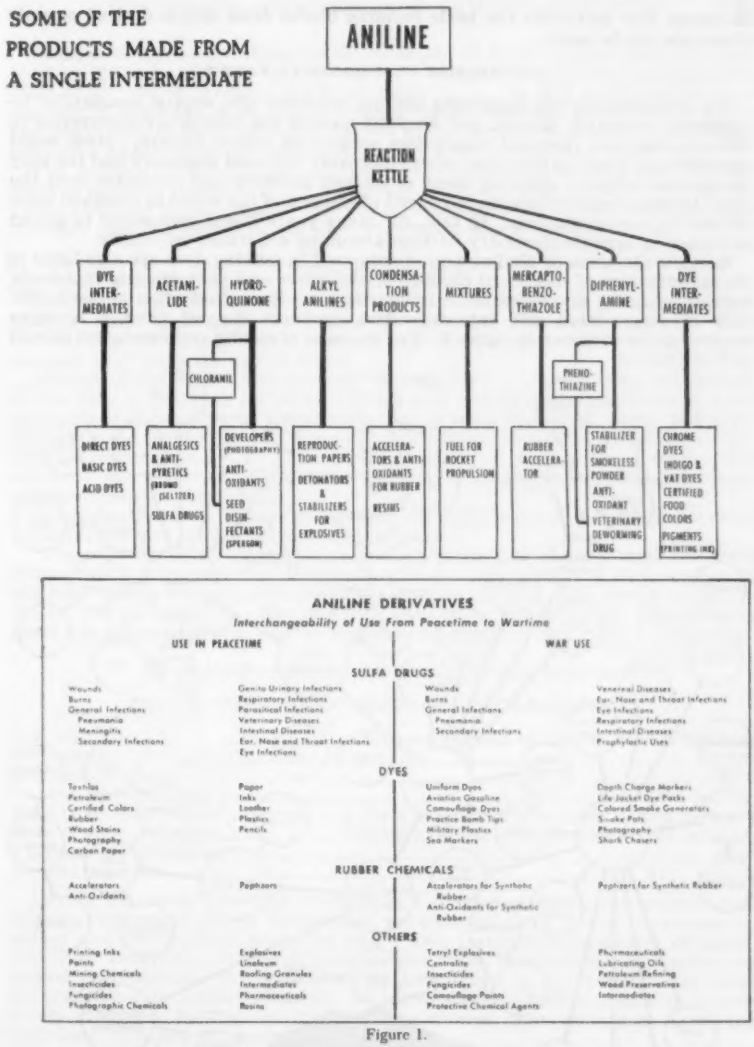
In 1828, a German scientist, Friedrich Wohler, discovered that carbon compounds could be made chemically (in imitation of natural substances) combining carbon with inert or inorganic, never-living material. This put an end to the old theory that all organic compounds contained a vital principle which only nature could produce; it also stimulated research in a vast new field of chemistry, and later made possible Perkin's synthetic dye.

Following Wohler's remarkable discovery, other investigators began to build simple carbon-containing compounds—literally new substances, not previously found in nature.

Today the technical handbooks list more than a half million organic compounds. These far outnumber the naturally occurring compounds which have been identified and, since they are manmade (by combination and rearrangement of carbon atoms with atoms of other elements to form other entirely distinctive, complex organic compounds), they are called synthetic. Some of the products obtained from a single intermediate are shown in figure 1, upper section.

Of the more than half million known compounds, most are simply laboratory curiosities. They offer variations on the known and useful properties of the thousands of organic chemicals regularly produced in this country. Many of them, however, hold great promise and are constantly being screened in research laboratories to find out if their minor differences in molecular architecture might make their differing properties better suited than present compounds for a given enduse.

The number of potential organic chemicals that could be synthesized reached astronomical proportions. For example, within the single series of compounds of carbon and hydrogen of the type chemically known as paraffins which are



ANILINE DERIVATIVES

Interchangeability of Use From Peacetime to Wartime

USE IN PEACETIME		WAR USE	
SULFA DRUGS			
Wounds Burns General Infections Pneumonia Meningitis Secondary Infections	Gen-to Urinary Infections Respiratory Infections Parasitical Infections Veterinary Diseases Intestinal Diseases Ear, Nose and Throat Infections Eye Infections	Wounds Burns General Infections Pneumonia Secondary Infections	Venereal Diseases Ear, Nose and Throat Infections Eye Infections Respiratory Infections Intestinal Diseases Prophylactic Uses
DYES			
Textiles Petroleum Certified Colors Rubber Wood Stains Photography Carbon Paper	Paper Inks Leather Plastics Pencils	Uniform Dyes Aviation Gasoline Camouflage Dyes Practice Bomb Tips Military Plastics Sea Markers	Depth Charge Markers Life Jacket Dye Packs Colored Smoke Generators Smoke Pots Photography Shark Chasers
RUBBER CHEMICALS			
Accelerators Anti-Oxidants	Peptizers	Accelerators for Synthetic Rubber Anti-Oxidants for Synthetic Rubber	Peptizers for Synthetic Rubber
OTHERS			
Printing Inks Paints Mining Chemicals Insecticides Fungicides Photographic Chemicals	Explosives Linoleum Roofing Granules Intermediates Pharmaceuticals Resins	Tetryl Explosives Centralite Insecticides Fungicides Camouflage Paints Protective Chemical Agents	Pharmaceuticals Lubricating Oils Petroleum Refining Wood Preservatives Intermediates

Figure 1.

found in our natural gas and petroleum, a calculation shows that there are 3 million possible compounds made up of 20 carbon atoms and 42 hydrogen atoms. Similar astounding possibilities are evident in working with other important series of compounds such as the alcohols.

As the complexity of chemical compounds grows by the introduction of atoms of other elements and different arrangements of atoms, the possibilities for creating new compounds, and therefore new materials with different characteristics, stagger the imagination. Yet any one of these myriad possibilities may yield a material to serve an important purpose for mankind.

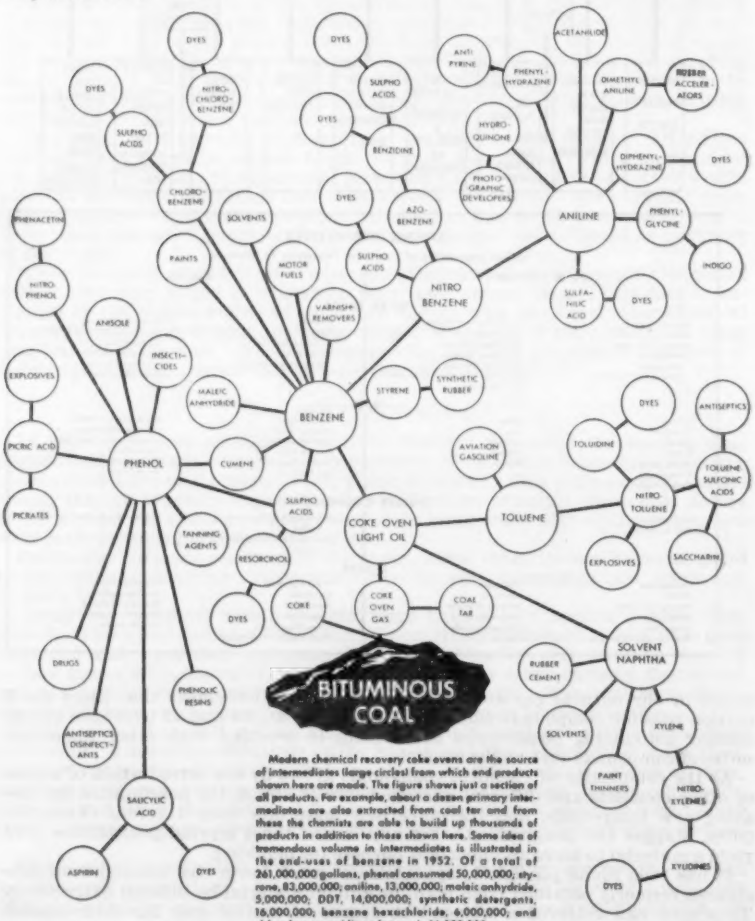
It has been found possible to synthesize at much lower cost thousands of substances formerly obtained from plant or animal material by difficult extractions. Thus man has achieved a tremendous degree of control over his environment. Chemists are confident they can make any compound they can analyze. What synthesis has accomplished is literally remaking the world—deriving from

abundant raw materials the basic building blocks from which desired organic chemicals can be made.

THE INDUSTRY FLOURISHES IN EUROPE

Not long after Perkin discovered his first synthetic dye, mauve, commercial interests in Germany, France, and England quickly put laboratory discoveries to business use and chemical enterprises sprang up across Europe. Most rapid progress was made in Germany where discovery followed discovery and the very prosperous industry, drawing many of its new products and processes from the great German universities, forged ahead of the rest of the world in chemical manufacturing and marketing. In fact, for many years it was impossible to get an education in organic chemistry without attending a German university.

Because the same or similar ingredients used in making dyes are also basic to the manufacture of medicinal chemicals, explosives and photographic chemicals, Germany rapidly developed these industries too. Some indication of the multitude of interrelated and interdependent products derived from a common source—coal—is shown in figure 2. For the sake of clarity representative groups only are shown.



Modern chemical recovery coke ovens are the source of intermediates (large circles) from which end products shown here are made. The figure shows just a section of all products. For example, about a dozen primary intermediates are also extracted from coal tar and from these the chemists are able to build up thousands of products in addition to those shown here. Some idea of tremendous volume in intermediates is illustrated in the end-uses of benzene in 1952. Of a total of 261,000,000 gallons, phenol consumed 50,000,000; styrene, 83,000,000; aniline, 13,000,000; maleic anhydride, 5,000,000; DDT, 14,000,000; synthetic detergents, 16,000,000; benzene hexachloride, 6,000,000; and chlorobenzene (di and mono), 16,000,000.

(Figure 2.

Because of the interrelation and interdependence of one organic chemical upon another, if the market for one is cornered by manipulating prices, the production costs of all related products can be seriously upset. In fact, such manipulation was one of the ways in which the German cartels operated to discourage chemical production in other countries and one of the reasons why America's development of a domestic organic chemical industry was blocked until Word War I.

The German chemical industry, which was deliberately fostered as an instrument of national policy, took full advantage of its vast coal deposits. The Allied Powers learned to their dismay how complete the German control of the chemical industry was and how deficient they were when war broke out in 1914.

AMERICA CATCHES UP

Fortunately a few American companies had been carrying on their own research. Although lagging far behind the Germans who closely guarded their secrets, they had a basis which enabled them to initiate synthetic organic chemical manufacture in the United States.

Because of the British blockade and German embargo, the industry did succeed by the time of our entry into World War I in providing a bare minimum of those materials indispensable to the manufacture of some explosives, drugs and dyes. Millions were spent in research to catch up. Chemical makers supplied military needs of every type. When the war ended, industry and the Government, fully aware of the country's recent crisis, resolved to establish America's own independent source of chemicals.

President Woodrow Wilson recognized the importance of a thriving domestic chemical industry, and in 1919 advised Congress:

"The experiences of the war have made it plain that in some cases too great reliance on foreign supply is dangerous, and that in determining certain parts of our tariff policy domestic considerations must be borne in mind which are political as well as economic. Among the industries to which special consideration should be given is that of the manufacture of dyestuffs and related chemicals."

III. Distinctive Characteristics of the Industry *

The American synthetic organic chemical industry today

Growth rate	4 times average of United States industry
Employees	153,000
Research workers	12,203
Annual research bill	$204 million
Rate of production gain	3 times average of all United States industry
Rate of sales increase	5 times average of all United States industry
Average hourly wages	$2.08
Annual payrolls	$717 million

During the years following World War I the American organic chemical industry, encouraged by an enlightened government tariff policy, increased research and development programs which soon resulted in expansion of manufacturing facilities. Research laboratories were established and staffed by skilled professionals. At the same time, stimulated by the demand and outlet for professionally trained chemists, the university and college chemistry departments expanded, both in turning out more trained chemists and in increasing their own fundamental research programs.

As a result, for the first time the American chemical industry and the universities made important contributions to medicine, synthetic fibers, plastics, agricultural chemicals, and other fields. Also, two important national resources were firmly established—an independent chemical industry and a growing body of scientists and skilled technicians to advance our industrial progress and strengthen our national security. It was the availability of these resources that enabled our country to meet successfully the challenges of World War II, and the tremendous demand for chemicals that developed in the post-war period.

A BILLION FOR RESEARCH

The chemical industry leads all others in the size and scope of privately financed research. If the present rate of $200 million a year is maintained, the organic chemical industry alone will spend $1 billion during the next 5 years for research and development.

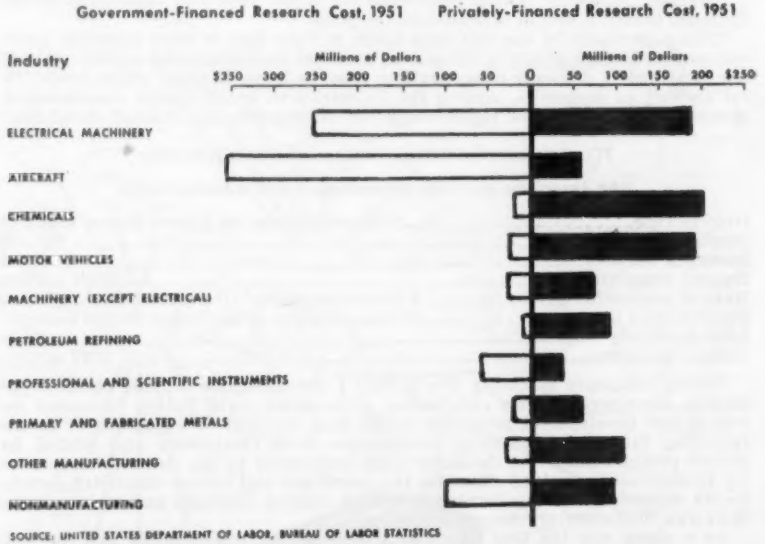
President Eisenhower on March 17, 1954, said:

"Science has a vital role in our Nation's security and growth. During the past half-century, it has brought about a vast transformation in industry, in agriculture, in medicine, in transportation, and in communications. Military science has been revolutionized by technological development. The impact of science is increasingly felt in every field of public policy including foreign affairs. All this has been brought about through a combination of vision, initiative, business enterprise, a strong educational system, and the dedicated enthusiasm of the scientific community."

The cost of research and the training of scientists, which adds up to 5 cents out of every dollar of chemical sales, must be paid out of earnings. So long as the chemical industry remains economically sound and is not subjected to unfair foreign competition, it will continue to lead in scientific achievement and technological progress.

The policy decision on the part of the Government, to aid and encourage the development of an American chemical industry, has had far-reaching consequences for the welfare of the entire country, for it encouraged the industry—reasonably assured of a continuing market— to invest additional huge sums in its own research. This constant search for improvement has made the chemical industry one of the greatest forces in our time for advancing our industrial complex and improving our standard of living.

CHEMICALS LEAD ALL INDUSTRY IN PRIVATELY FINANCED RESEARCH



INTEGRATION AND INTERDEPENDENCE OF PRODUCTS AND PROCESSES

One of the most distinctive characteristics of the chemical industry is its high degree of integration and the interdependence of its processes, particularly where large quantities of raw materials are processed by many successive steps into smaller amounts of greater numbers of intermediate products to produce a host of different end products. The completion of a single dye usually requires the consumption of from 10 to 80 times its weight of various raw materials. Figure 3 shows the many complex reactions over a period of months necessary to make defense dyes.

It can be seen from the chart why the chemical industry is its own best customer. No company makes all chemicals, and to carry on the complex processes illustrated, the manufacturer may be called on to obtain chemicals from a score of suppliers. This makes it highly important, when target goals must be met,

to accord priority to chemical production generally; otherwise, for want of a single compound the entire operation might be stopped. As stated in 20th Century Minutemen, a report to the President by the National Security Training Commission, December 1, 1953: "If there is another world war, we will not be granted the two years' grace we had in 1914 and 1939. The Kremlin would not repeat the error the Germans made twice in too recent history; we would probably be attacked first."

EXPANDS OUR RESOURCES

Organic chemicals add to America's store of total resources, for unlike other industries which process exhaustible raw materials, the chemical industry is not confined to any single source of supply. To obtain its intermediates and through them its finished products, it utilizes abundant coal, nitrogen from the air, crude oil and natural gas (all the petrochemicals made in 1953 used less than 1 percent of the crude oil processed), and it can switch from one to the other as costs change. Many chemicals once obtained by destructive distillation of wood may today be made from either petroleum or coal. The industry also efficiently utilizes agricultural wastes (furfural, a material used in making nylon, is obtained from oat hulls and corncobs). In other words, using every last component, chemistry upgrades materials which are in almost inexhaustible supply and which previously were considered undesirable or waste products. Coal tar, thrown away for many years, is the source of a dozen primary intermediates from which the chemist is able to synthesize a hundred thousand compounds.

In considering the dwindling natural resources which emphasize the present position of the United States as a "have not" country, the President's Materials Policy Commission has declared:

"The chemical industry differs from other industries chiefly in the fact that it has tremendous flexibility, both in the raw materials it utilizes and in its processing techniques. It has a unique facility for processing abundant raw materials not only into products suitable as substitutes for other materials, but also into new materials having new properties and superior to anything previously known.

"In the United States, the chemical industry may be considered to have come of age only after the First World War. Since that time, it has made phenomenal progress by concentrating intensively on research and development. Practically every industry is dependent on the chemical industry to a considerable degree, and this is also true of every household and consumer. The chemical industry itself is one of its own best customers. Heavy annual investments both in research and in plant have been necessary to achieve these results. Continued heavy investment is necessary for further development * * *.

"The chemical industry in the United States faces no long-term problems of raw materials supply * * *."

IMMEDIATELY CONVERTIBLE FOR DEFENSE REQUIREMENTS

By its very nature, the output of the chemical industry is instantly convertible to national defense. A drug which cures pneumonia will cure this illness in a soldier as well as a civilian. Dyes for work clothes are also dyes for uniforms. Insulating plastics for automobile motors are equally essential to bomber engines. Thus thousands of chemicals useful in peacetime applications are immediately useful for defense simply by changing the end use. This interchangeability is shown in figure 1, lower section, where derivatives of aniline find essential applications for military as well as civilian consumption. There is really no conversion problem. Retooling is not a factor. Peacetime production capacity is capacity for defense. Almost at the flip of a switch chemical intermediates and their derivatives can be redirected and channeled to strictly defense needs. This has led to the designation of the chemical industry as "the minutemen of mobilization," because no lengthy changeover is necessary.

On the other hand, although there is this flexibility in choosing the type of products which can be made from available intermediates, the plants in which the intermediates are produced are usually designed for specific purposes and by no means are completely interchangeable.

Therefore, because these chemical installations take months and years to build, it is highly important, as the National Production Authority recognized, to have ample production capacity for these key intermediates. To meet the Nation's military requirements, the National Production Authority in 1950 and 1951 certified that higher capacity of over 200 industrial materials was needed. Fifty-

seven of them were for the essential chemical "starting materials." These were deemed to be of such importance that certificates of necessity amounting to $608 million were issued by the Government.

In a sense these intermediates are the core of defense mobilization; without adequate chemicals the steel, petroleum, lumber, paper, and glass industries could not meet target goals or produce materials up to military specifications.

COMPLEX SYNTHESES ARE COSTLY

In recent years hundreds of millions of dollars have been invested in new plants that produce chemical intermediates and end products. As an indication of this trend, the amount of new investment in the chemical industry in 1954 exceeds $20,000 per worker. While labor costs for a few large tonnage chemicals produced in such high capital cost installations are relatively low, this does not apply to hundreds of intermediates nor to thousands of more complex end products made from them. High labor costs are the norm in the production of dyes, drugs, medicinal, pharmaceutical, photographic, and food chemicals because these are "fine" chemicals which require exacting quality control and are customarily produced in small quantities by batch process in vats and other batch vessels. They are tailormade to rigid specifications, and the quantities produced do not lend themselves to automatic or semiautomatic round-the-clock output like that of a modern petroleum refinery.

This is also true in other countries. American organic chemical manufacturers are just as efficient and technologically alert as the most advanced manufacturers in other countries. But with the resurgence of chemical manufacturing abroad, and the fact that foreign chemical workers are paid only one-fourth to one-tenth American wages, the domestic industry would be faced with a competitive disadvantage through its labor costs, were it not for sensible tariffs.

Moreover, relative productivity here and abroad today is very poor evidence of what it will be tomorrow—if production is transferred overseas. For, as the number of units produced in the United States is decreased, the unit cost of its remaining production will increase disproportionately; and, as the number of units produced abroad is increased, the unit cost of such materials will decrease with accelerated tempo.

CHEMICALS COMPETE WITH EACH OTHER

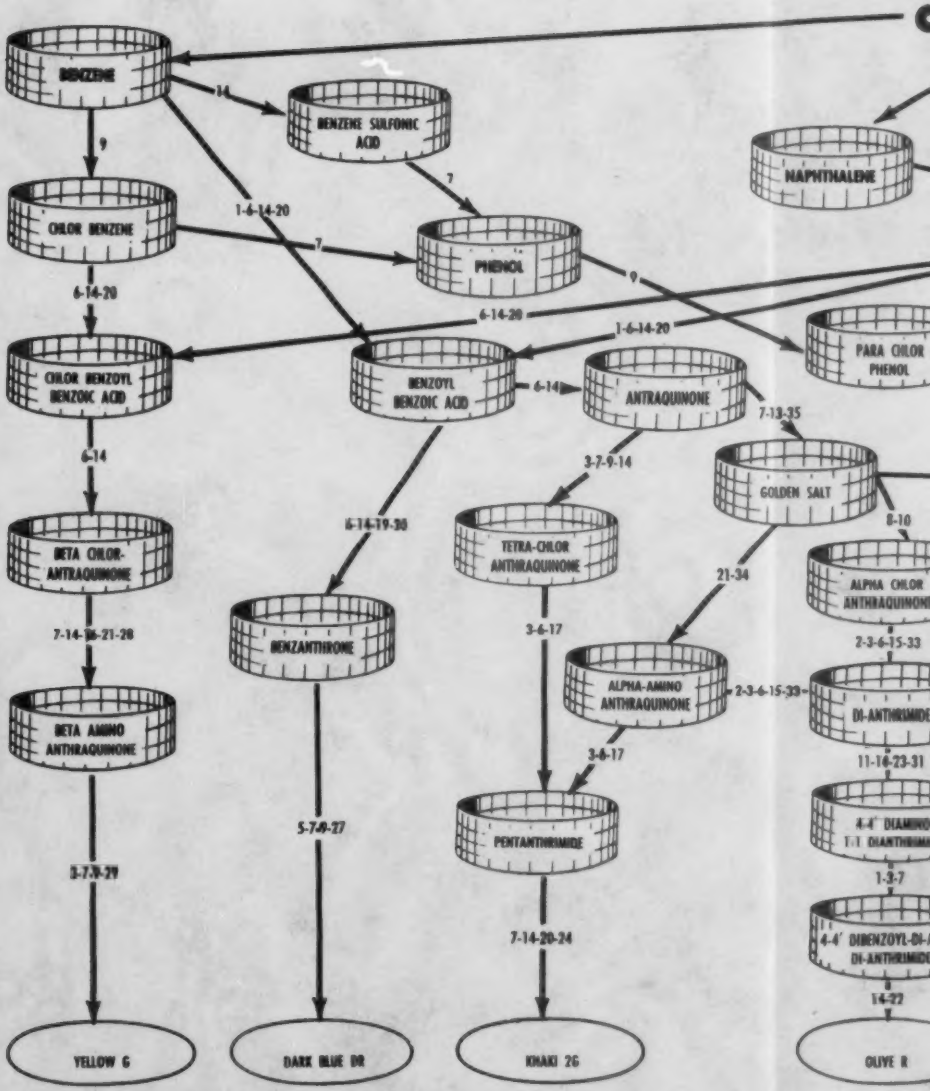
Because research is the very heart of the organic chemical industry and operates to stimulate competition, a company that is not moving forward aggressively with new cost saving processes and improved products is soon out of the running. No company has a market all to itself for very long. In terms of value, fully half of all organic chemicals offered today were not made commercially as recently as 15 years ago and new products continue to come out of chemical research laboratories at the rate of one a day.

The entrance of one company into the field of petrochemistry in 1925 was followed by dozens of others and today more than 100 individual chemical companies are using petroleum (natural gas, crude oil or derivatives) as a starting material for creating more than 2,000 end chemical products.

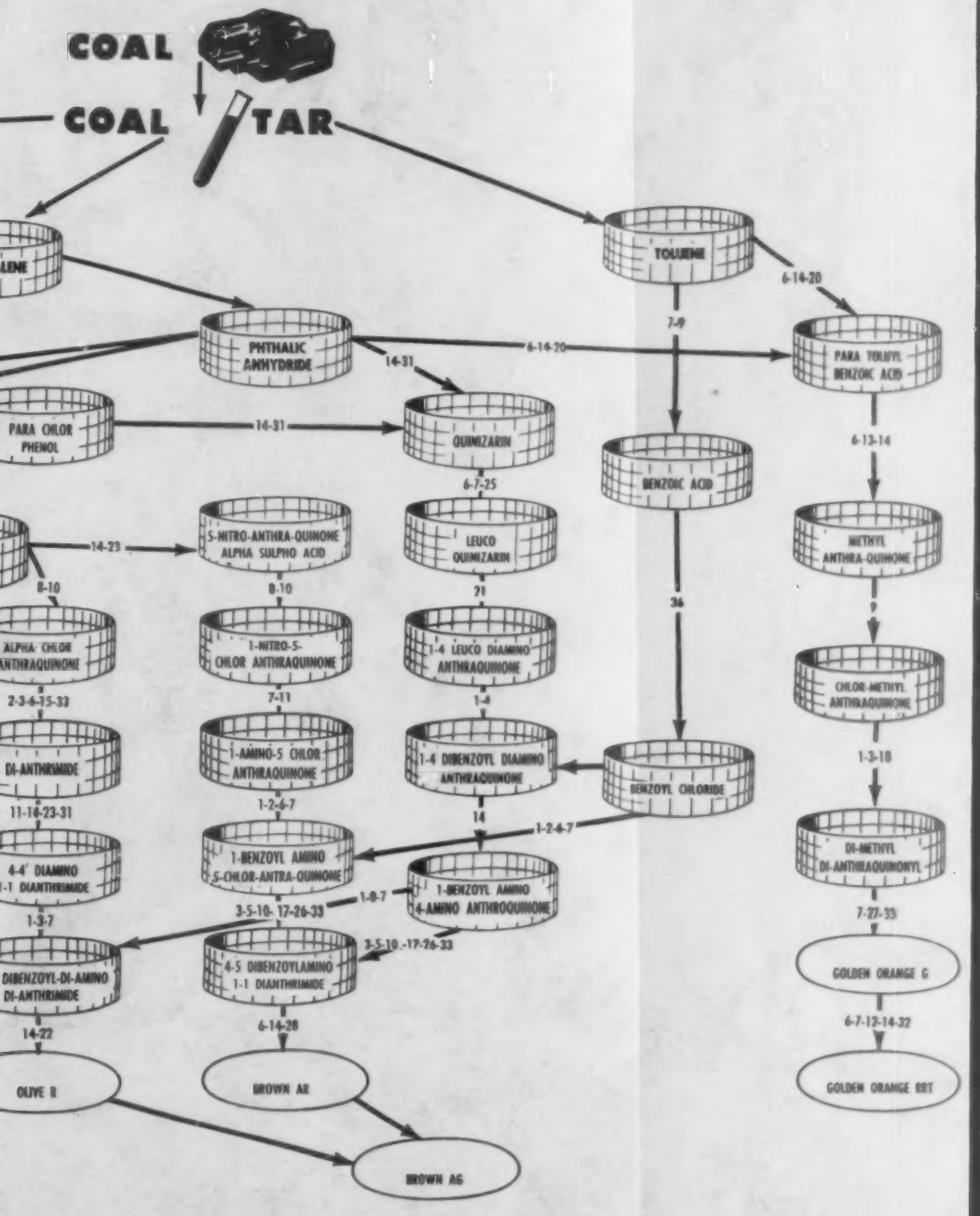
The chemical industry, particularly the fast-growing organic division, has been characterized by an everlasting juggling of materials and processes as research creates new knowledge. Chemical companies buy from and sell to each other a bewildering variety of compounds for selective processing and upgrading.

As one of the results of competition, chemicals have risen less in price than other commodities, even though the industry has incurred increased costs for labor, equipment and buildings.

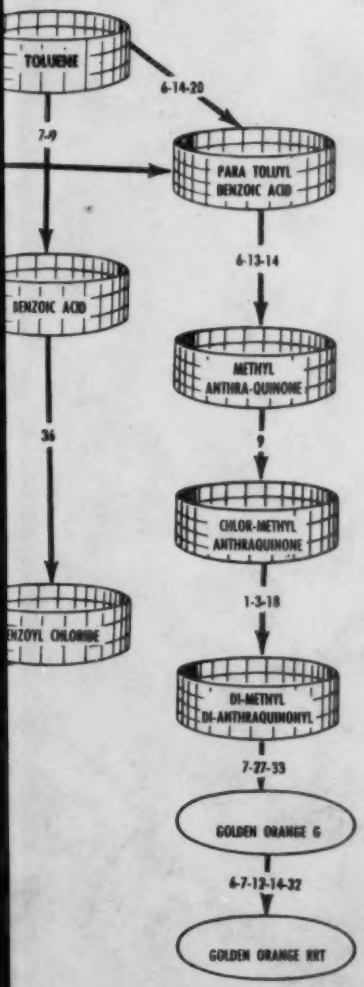
SCHEME OF SYNTHESIS



SIS OF SEVEN DEFENSE VAT COLORS



VAT COLORS



KEY TO ADDITIONAL CHEMICALS REQUIRED FOR SYNTHESES

1. Benzene
2. Di-Chlor Benzene
3. Nitro Benzene
4. Nitro Toluene
5. Sodium Acetate
6. Soda Ash
7. Caustic Soda
8. Sodium Chlorate
9. Chlorine
10. Hydrochloric Acid
11. Sodium Sulfide
12. Chlorsulfonic Acid
13. Oleum
14. Sulfuric Acid
15. Cuprous Chloride
16. Copper Sulfate
17. Copper Carbonate
18. Copper Bronze
19. Copper Powder
20. Aluminum Chloride
21. Ammonia
22. Sodium Nitrite
23. Mixed Acid
24. Urea
25. Sodium Hydrosulphite
26. Magnesium Oxide
27. Caustic Potash
28. Sodium Bichromate
29. Antimony Trichloride
30. Glycerine
31. Boric Acid
32. Bromine
33. Ethyl Alcohol
34. Nitrobenzene
    Sodium Sulfonate
35. Mercury
36. Prosphorus Chloride

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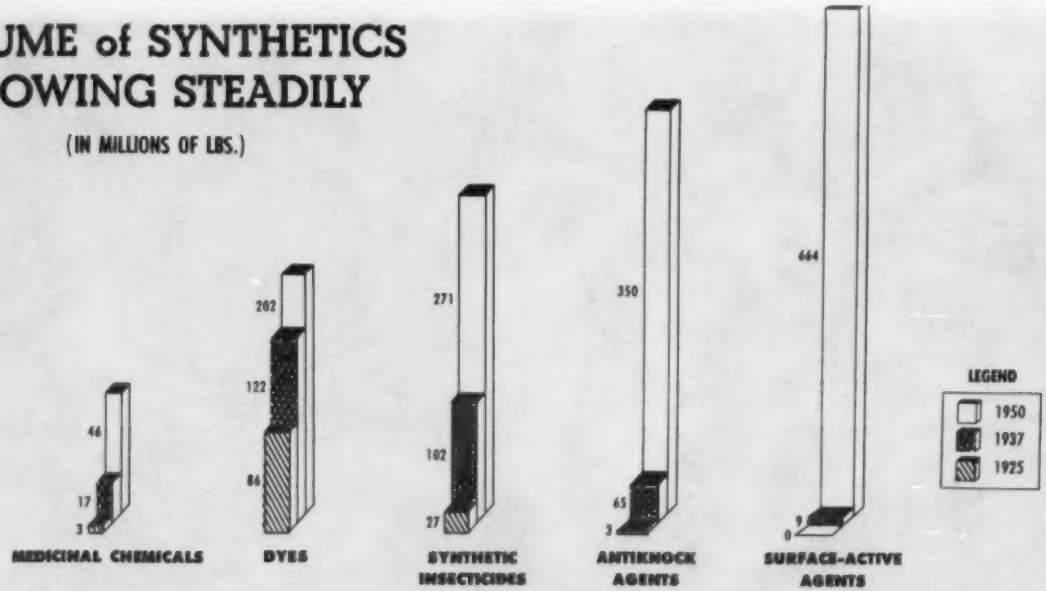
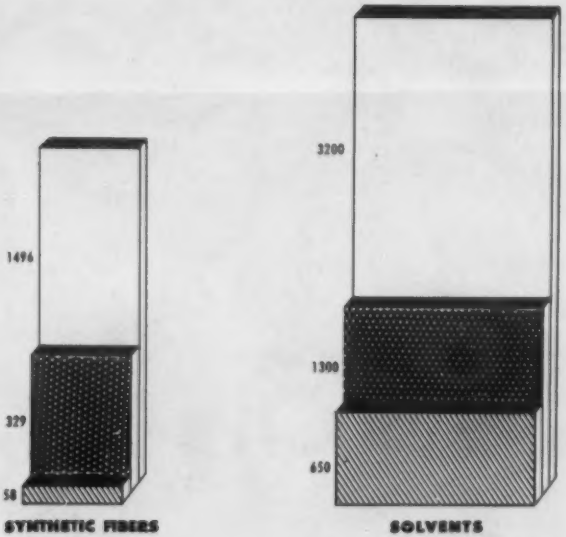
VOLUME of SYNTHETICS GROWING STEADILY

(IN MILLIONS OF LBS.)



MEDICINAL CHEMICALS | DYES | SYNTHETIC INSECTICIDES | ANTIKNOCK AGENTS | SURFACE-ACTIVE AGENTS

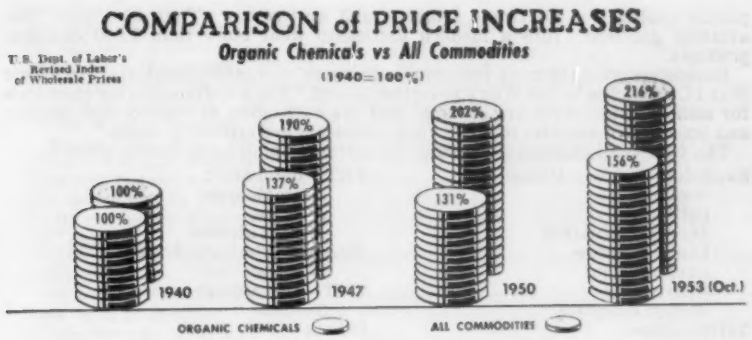
EXPECTATION OF GROWTH OF SYNTHETICS
1950 Production Represents 100%



SYNTHETIC FIBERS | SOLVENTS | SYNTHETIC PLASTICS

EXPECTATION OF GROWTH OF SYNTHETICS
1950 Production Represents 100%

OUTLINE of SYNTHETICS
CHEMICAL ENGINEERING



BASIC SUPPLIER TO ALL OTHER INDUSTRIES

In addition to supplying all of the major industrial groups with the chemicals they need in large amounts, chemical manufacturers actually have been the means means for creating such entirely new industries as plastics (which had a billion dollar sales in 1953 and employed more than 100,000 people) and synthetic fibers (which in 1954 accounts for 22 percent of all textile fiber production and exceeds 2,000 million pounds annually). Contributions to other industries are discussed in section V.

IV. Some Direct Contributions of the Industry to National Defense

Thanks to the chemical industry's continuing research program through the depression, America was able to meet the urgent chemical requirements of the embattled Allied forces after war broke out in 1939.

Military necessity caused the synthetic organic chemical industry to increase its production fourfold. America became the arsenal of democracy and with our own entry into the war, production was further stepped up with the largest part of the expansion for direct war use. For example, of the almost 15 billion pounds of organic chemicals produced in 1944, 92 percent had a direct military or essential civilian use as follows:

Category	*Percent with military or essential civilian use*
Intermediates	82
Dyes	72
Medicinals	69
Plastics and resins	100
Rubber processing materials	100
Elastomers	100
Surface active agents	100
Explosives	100
Plasticizers	99
Miscellaneous organic chemicals	90

Synthetic rubber is the most widely known example of the ability of the organic chemical industry to convert to a wartime basis and put its trained staff of researchers to work on an emergency project. The resourcefulness and ingenuity of the industry in developing know-how and training scientists, technologists and technicians provided a completely new $700 million industry within 18 months after the foreign supply of natural rubber was cut off.

In 1941 this country procured 1,311,000 long tons of rubber and latex of which 1,029,000 tons were natural, 274,000 tons reclaimed and 8,000 tons synthetic. In 1944 we were able to procure a new supply of 1,142,000 long tons of which 773,000 tons were synthetic and only 108,000 tons were natural and 261,000 tons reclaimed.

ORGANIC CHEMICAS AT THE FIGHTING FRONTS IN WORLD WAR II

The aircraft industry relied heavily on organic chemicals, with plane designers specifying more than 200 chemical components in each plane built. For example, chemicals were in domes and canopies, parachutes, instrument dials, insulation,

plastic coating for electronic systems, and antifreezes. They also went into aviation gasoline. Into a modern battleship went more than 1,000 chemical products.

Explosives were the most voracious consumers of organic chemicals. In World War II, according to the War Production Board, "The requirements for chemicals for military explosives are so large and are expanding so rapidly that present and prospective supplies of some vital chemicals are critically scarce."

The variety of chemicals required for certain explosives is shown below:

Smokeless powder—Propellant:
- Acetone
- Cellulose
- Dibutyl phthalate
- Dinitrotoluene
- Ethyl alcohol
- Ethyl ether
- Methyl cellulose

Tetryl primer:
- Acetone
- Aniline
- Methyl alcohol

RDX primers:
- Methyl alcohol

Ammonium picrate primer:
- Phenol
- Dinitrochlorobenzene

PETN detonator:
- Acetaldehyde
- Acetone
- Methyl alcohol

Mercury fulminate detonator
- Ethyl alcohol

TNT—Disruptives:
- Toluene

Others:
- Pentaerythritol
- Dinitrophenol
- Mannitol
- Diethanol
- Hexamethylamine
- Diethyl phthalate

Many other explosives and scores of mixtures and combinations were used for depth bombs, aerial bombs, incendiaries, trench mortars, rockets, rocket propellants, and flares. Explosives, however, accounted for only a small percentage of the number of defense items which the chemical industry supplied.

In equipping and protecting our armed forces and protecting their health, the organic chemical industry made one of its most important contributions to the war effort.

Each soldier required chemicals for his plastic helmet, dyes for his uniform, drugs and pharmaceuticals for his health, waterproofing for his equipment and outerwear, soap and detergents for sanitation and tablets for water purification. Penicillin, now a commonplace drug, owes its current availability entirely to a fabulous technical development which came through war needs. The Chemical Corps alone purchased over $150 million worth of 300 different chemicals exclusive of those in the heavy tonnage or explosives categories.

In addition to providing productive facilities for the many chemicals required for the war effort, the chemical industry served the Manhattan project and other work leading to the atomic bomb with both scientists and materials. Between 1950 and 1953 about 20,000 chemical company workers were employed at 8 AEC installations. At the present time, almost 4,000 chemists and chemical engineers are employed in AEC projects.

More than 1,500 different organic chemicals were used directly or indirectly for explosives and other necessary materials by the Armed Forces during World War II and at least 100 others were developed and used in Korea. The number of chemicals used in World War II breaks down into the following classifications:

Coal tar crudes	14
Cyclic intermediates	639
Dyes, lakes, toners	352
Medicinals	78
Flavor and perfume materials	19
Plastics and resin materials	68
Rubber processing chemicals	55
Elastomers	11
Plasticizers	31
Surface active agents	13
Pesticides and other agricultural chemicals	29
Miscellaneous synthetic organic chemicals	277
Total	1,586

KOREA

By the time of the outbreak of hostilities in Korea the synthetic organic chemical industry had converted the war chemicals to their civilian counterparts. In

addition, the industry had continued to expand its postwar facilities to meet the increased requirements of the American consumer. The Korean emergency, although only a partial mobilization, superimposed tremendous military requirements upon the normal civilian needs. Many new military items such as bullet-proof vests, rockets, napalm bombs, jet fuels and new drugs required millions of pounds of chemicals. All in all, more than 100 new chemicals not available in World War II were put to use during the Korean war.

At the start of the Korean conflict, the organic chemical industry's production already was 1½ times that of World War II. The supply, however, was still insufficient to meet both military and civilian needs. By concentrating on shortages and increasing its plant capacities the chemical industry was quickly able to step up its production high enough to meet the swollen demands of this "guns and butter" period.

The Defense Mobilization Director's Advisory Committee, in its report of January 1953 states:

"The basic assumption we have accepted is that the Nation must maintain a high level of military preparedness over a period of years—a wholly new concept in our history.

"The enormous potential of the United States for turning out weapons and implements of war acts as perhaps the greatest single deterrent to would-be aggressors. The Nation must not permit recurrence of the mistake made after the First and Second World Wars of letting its industrial machine for mobilization deteriorate or be liquidated.

"This country must avoid any national policy that would impair military end-item production lines."

V. Contributions to the General Welfare in Serving Industry and Agriculture

INDUSTRY

Organic chemicals now rival steel, copper and aluminum as important basic materials. Practically every manufacturing process depends upon synthetic organic chemicals at one stage or another although they are seldom visible in the finished product. The table shows, in order of their importance, industries currently using more than $100 million worth of chemicals yearly.

MAJOR CHEMICAL-USING INDUSTRIES

Chemicals	Miscellaneous manufacturing
Food and kindred products	Apparel
Agriculture and fisheries	Leather and leather products
Textile mill products	Stone, clay, and glass products
Rubber products	Motor vehicles
Petroleum and coal products	Iron and steel
Paper and allied products	Printing and publishing
Electrical machinery (except motors and generators)	Nonferrous metallurgy

The automobile industry may be used as an illustration. In 1953 that industry consumed organic chemicals valued at $590 million, a fivefold increase over the 1947 figure. The dollar volume consumption alone is a surprisingly large figure, but equally significant is the fact that the automotive industry estimates that 256 different chemicals are used directly or indirectly in the production of automobiles. The tires are synthetic rubber made with organic chemicals. The upholstery now uses synthetic fibers and plastics as well as dyes. Synthetic resins can be found in the ignition system, the steering-wheel fittings, safety glass and in the body finish. Permanent antifreeze and the hydraulic fluids are products of this industry and so is the tetraethyl lead in gasoline.

It is interesting to note that the products of the synthetic organic chemical industry have made possible some of our fastest growing consumer items since 1946. While it is not commonly recognized, room air-conditioning units, farm and home freezers, and the preparation and transportation of frozen foods all require chemical refrigerants. Frozen foods require millions of pounds of chemical films and wrappings and dozens of chemicals are used in manufacturing metal, glass, and paper containers. Synthetic detergents and synthetic fibers are wholly chemical products. A score of chemicals are used in television sets to insulate wiring, to make picture tubes, in treating alloys and metals for parts, and in alkyd resins for the tough, scuffproof coatings and finishes.

Thus the chemical industry makes possible products that have won the high acceptance of consumers. In helping industry to create this market, the chemical industry itself finds an increasing market for its products. Indeed the industry exerts a catalytic force in our economy which results in a continuous expansion of all industry and an endless profusion of new materials and end products of great value to this Nation's health, prosperity, and national defense.

Some of the ways in which organic chemicals enter into everyday products

Food.—Preservatives, flavoring, solubilizers, thickening agents; plastic film wrappers for meat and vegetables; nontoxic lacquers for food containers and beer cans; plastic materials for cappings, closures, and packages; therapeutic additives for food fortification; dietary adjuncts and sweetening agents.

Clothing.—Rayon and other synthetic fibers such as nylon, dacron, dynel, orlon, etc.; dyestuffs for fabrics; moth-repellents, mildewproofing and other finishing agents for textiles: tanning agents for leather accessories; plastic buckles, buttons and jewelry; shoe polishes, dry-cleaning fluids and detergents.

Household.—Paint on the walls, woodwork, and ceilings; varnish on the floors, woodstains on the furniture; synthetic fabrics and chemically treated natural fabrics, used in rugs, upholstery, draperies; the dyestuffs used to color all these fabrics; adhesives and binding and molding resins used in paneling; waxes, polishes, and detergents.

Medicine chest.—Proprietary remedies, ethical prescriptions, toothpastes, soaps, deodorants, cosmetics, shaving preparations, lotions, etc.

Automobile.—Synthetic rubber in tires, tubes, floor mats, hose connections, calking, vibration-free engine mounts and windshield-wiper blades; enamel finishes, interior and exterior; undercoating; insulation for electrical circuits; gasoline and motor-oil additives; antifree, both temporary and permanent type; radiator flushes; wax polishes, cleaners, and detergents.

Reading matter.—Printing inks, dyes to color paper; dyes to offset natural color in paper and turn it white; paper coatings; plastic inserts; adhesives for binding, etc.

AGRICULTURE

Agriculture is also a large consumer of organic chemicals. Organic insecticides, fungicides, fumigants, plant hormones, preservatives, disinfectants, weed killers, soil conditioners and feed supplements are already widely used in food production and will become increasingly important as our population grows.

Since 1920 this Nation's cropland has remained at approximately 400 million acres, while the population increased about 51 percent. Yet today—when our farm population is 22 percent less than it was in 1920—the same number of acres yield almost 50 percent more food. Although mechanization and release of farm animal feed acreage are responsible for part of this greater yield, the application of tailormade farm chemicals, including more than 4,000 chemical formulations for the control of insects and plant diseases are chiefly responsible for increasing farm productivity.

Organic chemicals assure more and better meat and dairy products. With special medicinals and pesticides and with chemically fortified feed, cattle, hogs and poultry are more productive, faster growing and offer a greater food yield.

Chemistry also creates new uses for farm crops, farm wastes, and animal products as basic materials for industry. The organic chemist has been called the link between the farmer and industry, for—through modern chemical technology—he can turn waste products into plastics, synthetic fibers, paints, paper and other products. Putting organic chemistry to work in this manner not only aids the farmer, but also conserves diminishing natural resources.

The organic chemical industry is working to provide still better chemicals to yield bigger and better harvests, to create abundance out of growing scarcity, and to cut the cost of food production. Working in a climate of freedom in which there is continued incentive and reward, the synthetic organic chemical industry may be relied upon to advance the frontiers of agriculture and to solve man's oldest and most basic problem.

VI. A Brighter Tomorrow

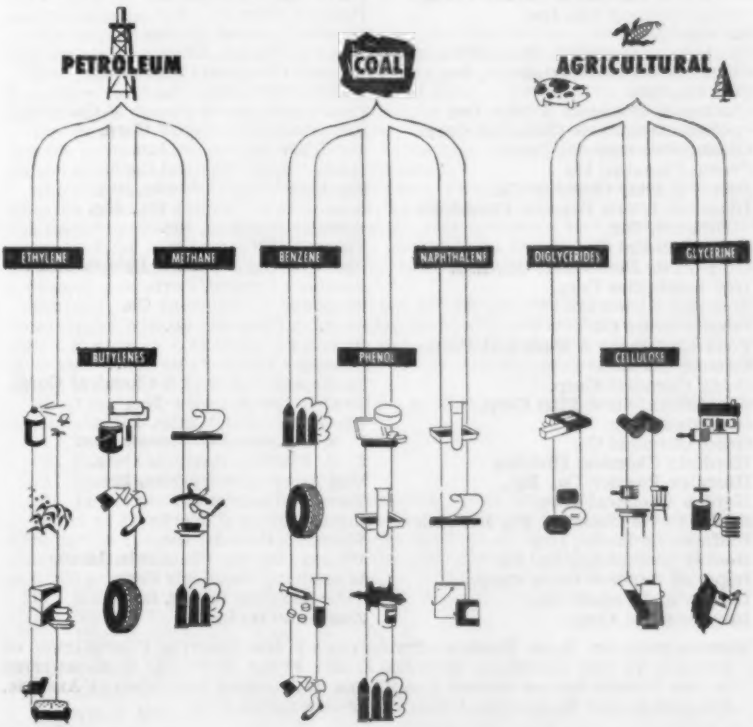
The reason why the country is seriously concerned with its defense is, of course, to maintain freedom and opportunity for the individual. This is the American creed and under this system, which respects the worth and dignity of the individual, this country has achieved its greatest strength. We have made possible more good things for more people than any civilization in history.

Where enterprise has been relatively free as in the chemical industry, we have a case study of how real national wealth is actually created. Working through chemical synthesis, materials of a variety and quantity undreamed of a generation ago have enriched the whole economy and furthered our standard of living.

The products of chemistry work most directly to stretch each individual's purchasing power. They do this by multiplying the work that one pair of hands can do in a day's time. For example, corn goes to the feeding lots and arrives at our dinner table in the form of pork chops at a more reasonable price because the farmer by using weed-killing chemicals cuts his cultivation costs 90 percent. The hog raiser uses feed supplemented with antibiotics to promote maximum growth. The new synthetic fibers in apparel last longer and save maintenance bills. A hundred examples could be cited how the individual has more leisure, or more time for full development, or how he saves money on necessities which can be used to purchase additional comforts and conveniences.

Impressive as the synthetic organic chemical industry's achievements have been, the research that is being done now and the vigorous, dynamic character of this industry augur an even brighter tomorrow.

HOW ORGANIC CHEMISTRY WORKS FOR MAN'S BENEFIT



● A FEW REPRESENTATIVE GROUPS

LISTED IN ORDER OF IMPORTANCE ARE LARGEST VOLUME END-CHEMICAL GROUPS

1. FIBERS
2. PLASTICS AND RESINS
3. MEDICINAL CHEMICALS
4. FERTILIZER MATERIALS
5. RUBBER
6. PIGMENTS
7. SOLVENTS
8. DYES
9. ANTIKNOCK AGENTS
10. SURFACE ACTIVE AGENTS
11. EXPLOSIVES AND PROPELLANTS, non-military
12. ALKALIS FOR MISCELLANEOUS PURPOSES
13. INSECTICIDES
14. LUBRICATING OIL ADDITIVES
15. ACIDS FOR MISCELLANEOUS PURPOSES
16. ANTIFREEZES
17. RUBBER PROCESSING CHEMICALS
18. BLEACHING CHEMICALS
19. CATALYSTS
20. REFRIGERANTS
21. WOOD PRESERVATIVES
22. GLASS MAKING CHEMICALS
23. PLYWOOD CHEMICALS
24. PHOTOGRAPHIC CHEMICALS
25. PERFUME CHEMICALS
26. EXPLOSIVES AND PROPELLANTS, military
27. DETERGENT BUILDERS
28. FOOD ACIDULANTS
29. GASES FOR WELDING AND CUTTING
30. WATER TREATMENT CHEMICALS

MEMBERS OF SYNTHETIC ORGANIC CHEMICAL MANUFACTURERS ASSOCIATION

Advance Solvents & Chemical Corp.
Alliance Color & Chemical Co.
Allied Chemical & Dye Corp.
National Aniline Division
Althouse Chemical Co.
American Aniline Products, Inc.
American Cyanamid Co.
American Dyestuff Reporter
American Dyewood Co.
Arnold, Hoffman & Co.
Atlas Powder Co.
Baker Chemical Co., J. T.
Bates Chemical Co., Inc.
Belle Chemical Co., Inc.
Benzol Products Co.
Berkeley Chemical Corp.
Carbide & Carbon Chemicals Co.
Union Carbide & Carbon Corp.
Carus Chemical Co., Inc.
Carwin Co.
Celanese Corporation of America
Chemical Manufacturing Co., Inc.
Ciba Co., Inc.
Cincinnati Chemical Works, Inc.
Columbia-Southern Chemical Corp.
Commercial Solvents Corp.
Crown Chemical Co.
Dewey & Almy Chemical Co.
Diamond Alkali Organic Chemicals Division, Inc.
Dow Chemical Co.
Du Pont de Nemours & Co., E. I.
Dye Specialties Corp.
Eastman Kodak Co.
Empire Trust Co.
Food Machinery & Chemical Corp.
Gamma Chemical Corp.
Geigy Chemical Corp.
General Aniline & Film Corp.
Givaudan Corp.
Grace Chemical Co.
Hardesty Chemical Division
Hercules Powder Co., Inc.
Heyden Chemical Corp.
Hilton-Davis Chemical Co. Division
Hoffman-La Roche, Inc.
Hooker Electrochemical Co.
Imperial Paper & Color Corp.
Industrial Dyestuff Co.
Interchemical Corp.
Jefferson Chemical Co.
Kay-Fries Chemicals, Inc.
Kolker Chemical Corp.
Koppers Co., Inc.
MacNair-Dorland Co.
Maschmeijer, Jr., Inc., A.
Mathieson Chemical Corp.
May, Inc., Otto B.
Maywood Chemical Works
Metro Dyestuff Corp.
Miller, Inc., Paul L.
Monsanto Chemical Co.
Montrose Chemical Co.
Newport Industries, Inc.
Niagara Alkali Co.
Nopco Chemical Co.
Oil, Paint & Drug Reporter
Patent Chemicals, Inc.
Peerless Color Co., Inc.
Pfister Chemical Works
Pfizer & Co., Inc., Chas.
Pharma Chemical Corp.
Phillips Petroleum Co.
Pittsburgh Coke & Chemical Co.
Poughkeepsie Dyestuff Corp.
Publicker Industries, Inc.
Reilly Tar & Chemical Corp.
Sandoz Chemical Works, Inc.
Schenectady Varnish Co., Inc.
Scholler Brothers, Inc.
Sherwin-Williams Co.
Smith, Kline & French Laboratories
Southern Dyestuff Corp.
Standard Ultramarine Co.
Stauffer Chemical Co.
Stepan Chemical Co.
Sumner Chemical Co.
Tennessee Products & Chemical Corp.
Trubek Laboratories, Inc.
Ultra Chemical Works, Inc.
U. S. Industrial Chemicals, Inc.
U. S. Plastics Products Corp.
Van Ameringen-Haebler, Inc.
Verona Chemical Co.
Victor Chemical Works
Wilmot & Cassidy, Inc.
Wilson Organic Chemicals, Inc.
Wyandotte Chemicals Corp.
Young Aniline Works, Inc.
Zinsser & Co., Inc.

MEMORANDUM ON RARE EARTHS—PRESENTED BY MOLYBDENUM CORPORATION OF AMERICA TO THE MINERALS, MATERIALS, AND FUELS ECONOMIC SUBCOMMITTEE OF THE UNITED STATES SENATE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS, SENATOR GEORGE W. MALONE, CHAIRMAN, NOVEMBER 10, 1954

Rare earths are a mixture of 15 metals which occur together in nature, the most common of these being cerium and lanthanum. For all except very special uses the 15 metals are not separated but are used all together, since they behave quite similarly chemically and metallurgically.

Our first activity in rare earths was in 1916, when we constructed the first rare earths metal plant in the United States.

Molybdenum Corp. has had 40 years' experience as a developer of uses for tungsten, boron and molybdenum products in steel and iron and as a miner and producer of products of these specialty metals. As a result of this experience and the experience in producing rare earths metal, we conceived the idea that

perhaps a large use could be found for rare earths products in steel and iron if sufficient supplies of rare earths were available within the United States.

At that time the only commercial sources of rare earths were the monazite sands of India and Brazil. During the late 1940's we started a search for rare earth deposits in the United States which culminated in our acquisition in 1951 of the Bastnasite property at Mountain Pass, Calif. Intensive work on this Mountain Pass property has proved it to be the largest source of rare earths and the mine is now comparable to the largest mines of specialty metals anywhere in the world.

With the acquisition of this property we concluded the second step of a pioneer undertaking, the first step having been the conception of the possibility of establishing a wide use for rare earths in metallurgical industries. The third problem, the successful working out of a method of beneficiating the ore at Mountain Pass (a difficult problem as the ore was unique in various ways), was next successfully solved. The last pioneer step, the creation of a market on a large scale for rare earths in the iron and steel industry, was simultaneously undertaken.

As a result of the work of the Molybdenum Corp.'s organization, we have now in successful operation a very large developed mine, and a mill which can treat 5,000 tons of ore monthly, producing at the rate of 8,500,000 pounds of rare earths oxide per year.

The work which we have done to create a market for rare earths in steel and iron on a large scale can perhaps be best explained chronologically.

The first metallurgical use of rare earths was in the form of misch metal, i. e., rare earths in the form of unseparated metals, which were added to those steels which were difficult to roll, particularly certain grades of stainless steels.

The next use was in cast armor plate. This resulted in the improvement of impact properties which means better ballistics. It was an important contribution to the production of better armor plate.

Knowing that the production of misch metal was much more costly and complicated than the production of rare earths oxides, we began to experiment with the use of oxides of the rare earths in steel. We developed and patented several compounds of rare earths oxides which proved to be as effective as misch metal in enhacing the hot working qualities of steel and which produced, in addition, a cleaner steel.

Initially, we were able to produce rare earths compounds to sell at a price competitive with misch metal. As we improved our processing at the mine and mill we were able to make successive and material reductions in price so that it is now economically advantageous to use rare earths in the low-priced steels which are produced in large quantities.

Speaking generally, we have been able to show that rare earths compounds, when added to steel:

(1) Increase hot workability
(2) Lower the sulfur content
(3) Increase the fluidity of the melt
(4) Lower the tapping and teeming temperature of the steel

While at the start of this work, immediate success was achieved in the use of rare earths compounds in stainless steels, the bulk of the work since our initial success has been done in the low carbon steels which have a history of being difficult to work and which are produced in large tonnages. Classified, these are:

(1) Killed steels of the low alloy 0.20 percent carbon range
(2) SAE 1020 series (low carbon)
(3) High sulfur steels of the 1100 series
(4) Silicon sheet steels
(5) Killed plate steels
(6) Semikilled plate steels such as ship plate

Important benefits were secured by adding rare earths (an average of 2 pounds or less per ton) to these steels to reduce tears, slivers and cracks during the rolling operation, thereby simultaneously eliminating, or greatly reducing, surface preparation. Yields of shipable steel have been, in consequence, increased and important savings in cost have been effected.

Some few examples are:

In seamless pipe, rejections due to internal defects resulting from piercing were decreased.

In silicon sheet steels edge losses and tearing were reduced and also a lower watt loss was obtained.

In sheet steels for deep drawing, material improvements in production were made.

In plate steels, banding, which is a serious defect in these steels, was reduced, thereby decreasing the possibility of ship plate failure.

In cast steels, impact values at low temperature were increased which is important in the case of armor and gun tubes in Arctic regions.

In nodular iron, i. e., high strength iron, the use of rare earths is standard practice.

The use of our rare earths compounds has been recently adopted by a plant of one large steel company for use as standard procedure in all steels of the 0.13 to 0.28 carbon range. Similar work in these and other types of low carbon and alloy steels is being concluded by most of the major steel companies.

Mention should be made of the possibility of substituting rare earths for manganese in those steels whose manganese specifications call for 0.5 and above. An addition of 2 pounds of rare earths per ton enables manganese specifications to be reduced from approximately 0.80 to approximately 0.40, giving equal rollability, less surface preparation and an increase in shipable yields. Thus it is indicated that 2 pounds of rare earths can replace 8 to 12 pounds of manganese in 25 million tons of steel, resulting in a saving of about 100,000 tons of manganese metal per year. Present relative prices of manganese and rare earths make this use marginal, but at a lower price for rare earths or in time of war, this application could be of great importance.

In summary, our company during the past few years has acquired and developed the largest deposit of rare earths in the world, thus making the United States completely independent of foreign sources of rare earths. We have successfully produced concentrates and rare earths oxides of high grade, thereby making available to industry products suitable for all intermediate and end uses of rare earths. We have developed compounds of rare earths for steel and iron metallurgy. Finally, we have conducted an extensive and successful program to build markets for rare earths in the steel and iron industry.

How large a tonnage of rare earths will be used annually cannot be estimated at the present moment with accuracy. However, our work has shown that rare earths could be used with economic advantage in 40 million tons of steel annually in the United States requiring about 60 million pounds annually of rare earths compounds.

In consequence, it can be reported that the use of rare earths in the steel and iron industry in large amounts is assured and that production of rare earths in the United States is adequate for this and any other industrial use for a very long period of time. Molybdenum Corp.'s mining and industrial development of rare earths, therefore, appears of importance to both the national security and the national economy.

MARX HIRSCH, *President.*

LYNN WILLIAMS ENGINEERING CO.,
Chicago, Ill., November 10, 1954.

MINERALS, MATERIALS, AND FUELS ECONOMIC SUBCOMMITTEE OF THE SENATE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Senate Office Building, Washington, D. C.
(Attention: Hon. George W. Malone, chairman.)

GENTLEMEN: We understand that your committee is concerned with plans for reducing the dependence of the United States on strategic materials not produced in this country. This statement is concerned with industrial diamonds. It deals with a method for reducing industrial diamond consumption to such a point that the reported stockpile of this material could be made to last for as long as 50 or even 100 years.

The greatest consumption of industrial diamond bort is in the grinding of hard materials, such as tungsten carbide, and it is to this field that the development here reported is applicable.

This development rests on a number of inventions of an American, George F. Keeleric, who now lives in Dundee, Ill. Some years ago, he discovered that hard materials, such as tungsten carbide, could be precisely shaped by removing the material electrolytically rather than by abrasion. This development has now been thoroughly tested by large industrial users and is ready for immediate commercialization.

The principle of the process can be understood by referring first to the ordinary process of electroplating by which it is common to deposit a plating of copper, nickel, or chromium on a metallic surface. In such plating operations, the metal—for example, copper—is removed from a copper anode suspended in a plating tank and transferred electrically to the part to be plated.

In the Keeleric process for shaping carbides this general principle is applied in reverse. The carbide is deplated by electrolytic action. The ordinary electroplating system would not be suitable for this purpose, partly because the rate of material removal would be much too slow and partly because it would not provide the precision needed for the shaping of tungsten-carbide pieces for use in industrial machining.

The Keeleric electrolytic deplating process accelerates the electrolytic action by several hundred times over that which would take place in an ordinary electrolytic plating system.

This process uses ordinary grinding equipment with only slight modification. A metal grinding wheel is used on the spindle of an ordinary grinder, and electrical energy is supplied in such a way as to pass between the metal grinding wheel and the tool or other part to be shaped. Instead of the ordinary coolant which flows over the work area, a water and salt solution is used which serves as an electrolyte. The salt is one of those which has normal rust-inhibiting properties, so that it does no harm to the machinery.

Abrasive particles project slightly from the surface of the metal wheel and, thus, prevent direct mechanical contact between the piece being shaped and the metal wheel. In the spaces between the abrasive particles, a violent electrolytic action occurs and removes material from the piece being shaped. This material does not deposit on the grinding wheel because of the nature of the salts which are being used.

The removal rate is at least as fast as conventional diamond grinding and many tests show that it is much faster. For example, tests were run by the Carborundum Co. on this system and showed a removal rate six times as fast as that achieved by conventional diamond grinding. In those tests the abrasive material used for the purpose of spacing the workpiece away from the metal of the metal grinding wheel were diamond particles. The Carborundum Co. reports that the life of these diamond particles was 100 times the life which would be expected in conventional diamond grinding. Accordingly, a year's stockpile of diamond bort computed on the basis of conventional diamond grinding would last 100 years, if every application were converted to electrolytic grinding. This may not be practical, as some quantity of diamond bort is used for grinding glass and similar nonconductive substances and for such use the electrolytic process is not applicable. It is applicable, however, to a very wide range of grinding tungsten carbide tools.

The National Academy of Sciences studied this problem, as you doubtless know, publishing a report, No. MAB–18–M, January 18, 1952. In this report the following table of the usage of diamond bort for grinding carbide tools was given (appendix I–9):

	Percent
(1) Single point tools (¾ inch square shank and under)	32
(2) Single point tools (over ¾ inch square shank)	8
(3) Special tools	15
(4) Mining and percussion	15
(5) Wear parts	10
(6) Standard dies	8
(7) Special dies	12

The first 4 applications listed, constituting 70 percent of the total, are immediately accommodated by the electrolytic process. The remainder, constituting 30 percent, may be accommodated in many instances by the development of appropriate special machines.

The process has been developed to the point where the speed of operation is more than equal to the conventional diamond-grinding practice. The quality of the work, particularly the surface finish, is better than the regularly accepted in diamond-grinding practice.

The process has been undergoing tests in actual shop use for a number of years; some of the tests in large factories, others in smaller ones. Tests have been conducted by General Motors Corp. in its Buick, Frigidaire, and Electro-Motive plants with excellent results. In the oldest of these installations, at

the Frigidaire plant, the same grinding wheel has been used continuously for almost 2 years.

In a smaller plant, that of the Dodge Manufacturing Co. at Mishawaka, Ind., the same grinding wheel has been used for a year and a half.

The process is readily adaptable to existing machinery. All that is needed is to provide electrical insulation for the grinding spindle and a slip-ring arrangement for making electrical connection to it.

This company on whose behalf this statement is submitted has recently been formed for the purpose of manufacturing and distributing the electrical apparatus necessary for the general use of this process.

The process is applicable not only to tungsten carbide but to any conductive material. It is usable, for example, in the very rapid shaping of titanium, titanium carbide, hardened tool steel and armor-plate, as well as the softer metals: aluminum, brass, etc.

The equipment is now available for a wide range of applications. For many special applications, however, appropriate machinery still needs to be developed. It appears, also, that the maximum removal rates have not yet been attained inasmuch as many electrolytic solutions have yet to be tested. There is no reason to suppose that the electrolyte now being used represents the ultimately best material for this purpose.

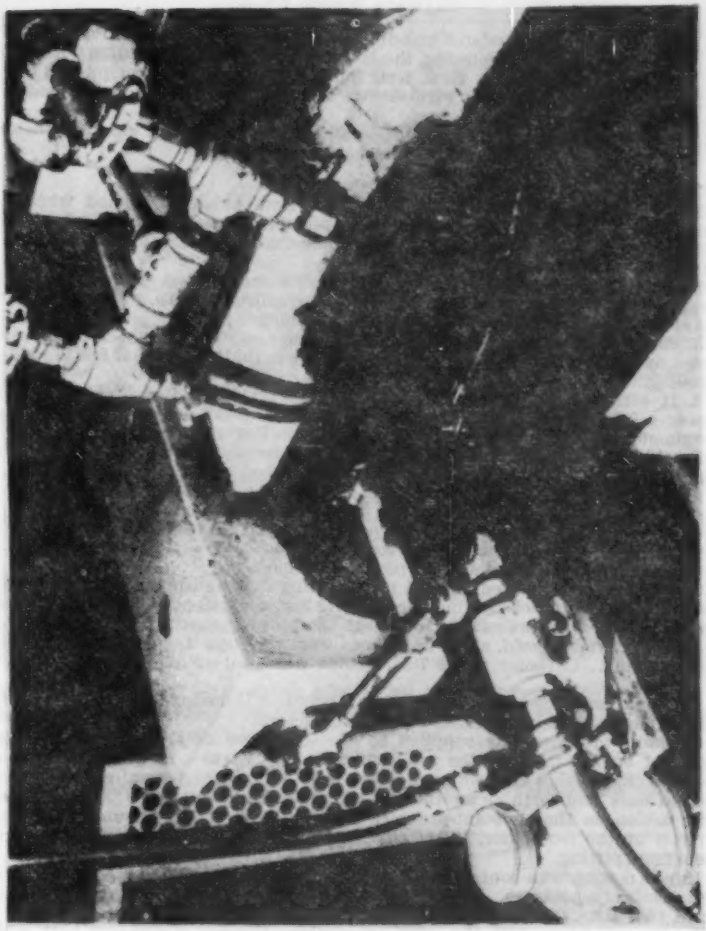
It is reasonable to suppose that within a relatively few years a large part of American industry can be served with this new process, so that the extent of diamond usage can be rapidly curtailed. At the same time, the availability of this process is likely to open up a wider application for the use of hard materials which has heretofore not been practical because of difficulties in machining and shaping.

We should be glad to supply your committee or any appropriate agencies of the Government with further information, and we should be glad to make appropriate demonstrations of the equipment and the process in whatever way might be helpful.

We attach a photostatic copy of the report of the Carborundum Co. entitled "How to Grind Carbides Six Times as Fast with Less Than 1 percent Diamond Wheel Wear."

Respectfully submitted.

LYNN WILLIAMS ENGINEERING CO.,
By RENU A. LILLIE.



THE ELECTROLYTIC GRINDING operation showing the ball bearing fixture, air cylinder, variable speed drive, and dual nozzles for electrolyte solution

How To Grind Carbides Six Times as Fast With Less Than 1 Percent Diamond Wheel Wear

Electrolytically assisted grinding of carbides, although relatively new, shows promise of replacing the conventional form of grinding (AM—Nov. 10, 1952, p. 154). Now, tests indicated this can be accomplished on a sound practical basis with standard equipment and diamond wheels.

(By John A. Mueller, manager mechanical lab department, sales engineering branch, Carborundum Co.)

Tests results at carborundum established that:

1. Electrolytically assisted grinding with metal-bonded diamond wheels, as compared to conventional grinding with resinoid-bonded diamond wheels, provides a method of grinding cemented carbide that is as fast, or faster, and uses only a fraction as many diamonds.

2. It produces tools whose microinch finishes are as good as those of conventionally ground tools, and whose edges are equally as sharp, provided they are not subjected to the electrolytic action for a prolonged period.

3. Electrolysis will generate a dull appearance on carbide, which can be eliminated by varying the technique of finishing the carbide in the last few seconds of grinding.

4. It consumes substantialy less spindle power in grinding carbides, but the power required for electrolytic assistance raises total power consumed to approximately two and one-half times that used in conventional grinding.

To obtain a measure of the practicability of the electrolytically assisted grinding process, the following objectives were established:

(1) To determine how fast cemented carbides can be ground.

(2) To determine whether diamond bort can be conserved.

(3) To determine the effect of the process on surface roughness, quality of the cutting edge and appearance of the ground carbide.

(4) To determine the amount of power consumed.

Our tests were directed toward the grinding of single-point tungsten-carbide tools, and consisted of holding the tool against a diamond wheel, with offhand pressure, and simultaneously traversing the tool across the wheel face. Work pressure, traverse speed, and wheel speed were the same as are generally used in tool grinding. Carboloy grade 78B carbide was used as it is relatively difficult to grind.

Principal features of the arrangement include a Hammond electrolytic carbide tool grinder, a selenium rectifier, and a wattmeter.

Constant pressure was supplied to the workpiece at all times by a fixture mounted on the table of the tool grinder. The fixture, A, consists of an air cylinder that pushes against a set of ball-bearing ways and simultaneously reciprocates back and forth on another set of ball-bearing ways. To prevent electrolytic action on the constant-pressure device, the electrical ground was placed directly on the toolholder. This minimized wear on the ball bearings and kept them from pitting.

Infeed motion was controlled by a pressure regulator, B, that could be set at any arbitrary pressure. Traverse motion was controlled by a variable-speed drive, C.

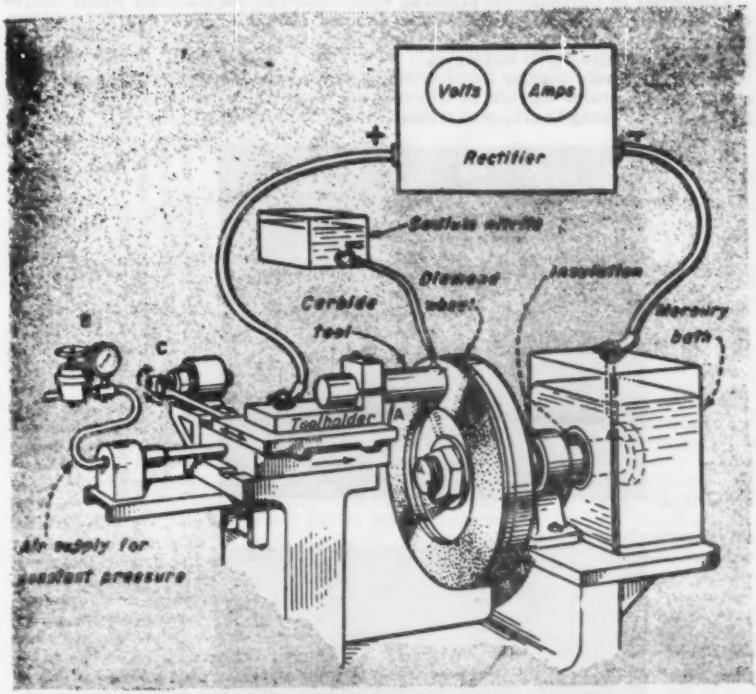
Power was brought to the grinding machine through a mercury bath and a metal disk mounted on the insulated wheel spindle. Voltage was varied to maintain as high a current density as possible without excessive workpiece sparking.

The rectifier circuit included a d. c. ammeter, a d. c. voltmeter and an a. c. ammeter. The a. c. ammeter served only as an indicator of sparking. At times, when there was no sparking visible, the a. c. ammeter would fluctuate and indicate the presence of sparking.

DISCUSSION OF RESULTS

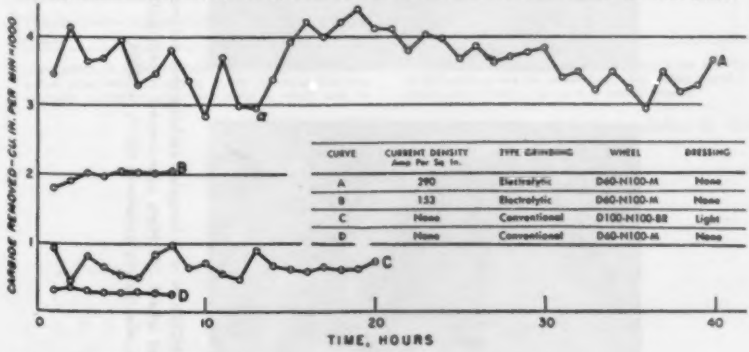
The effect of current on cutting rate is apparent by comparing curves A and B. By doubling current density—from 153 amperes per square inch to 290—the cutting is increased by about one and three-fourths times.

The assist given a metal-bonded diamond wheel by the electrolytic method is evident from the relationship of curve D with curves A and B. A current density of 153 amperes per square inch (curve B) increases cutting rate sevenfold, while 290 amperes per square inch (curve A) increases it by approximately 12 times.



GENERAL ARRANGEMENT of electrolytic grinding test setup. Diamond grinding wheel is exaggerated in size to illustrate more clearly the relationship of the diamond bort to the electrolytically assisted process

CARBIDE REMOVAL RATES OF ELECTROLYTIC GRINDING VS CONVENTIONAL GRINDING



CURVE	CURRENT DENSITY Amp Per Sq In.	TYPE GRINDING	WHEEL	DRESSING
A	290	Electrolytic	D60-N100-M	None
B	153	Electrolytic	D60-N100-M	None
C	None	Conventional	D100-N100-BR	Light
D	None	Conventional	D60-N100-M	None

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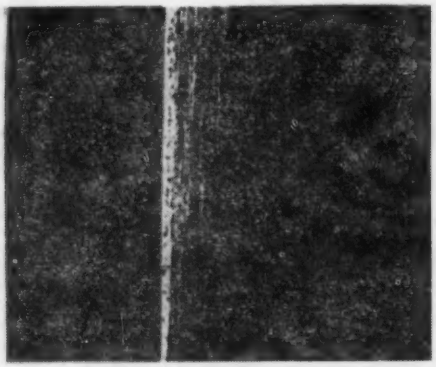
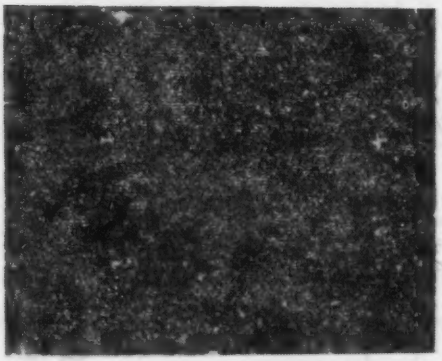
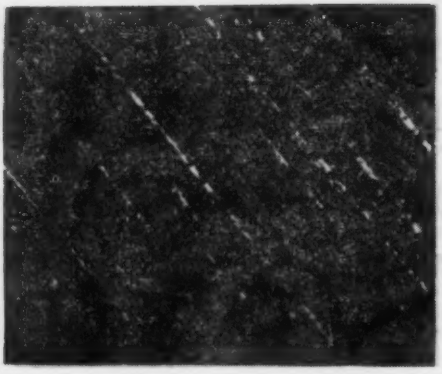
Compared to conventional grinding with resinoid-bond diamond wheel (curve C), the electrolytically assisted process doubles the cutting rate when 153 amperes per square inch is used, and increases the cutting rate by six times when the higher current density is employed.

The high current-density test (curve A) was continued for 40 hours in order to obtain a measurable amount of wheel wear, while the other tests were run only as long as necessary to arrive at reliable comparative data.



TYPICAL EDGE of many square-nose tungsten-carbide tools ground with 290 amp per sq in. electrolytic assistance and using a D60-N100-M diamond wheel. 20X





SURFACE CONDITION of a tungsten-carbide tool ground conventionally with a resinoid-bond diamond wheel. (A) Note pronounced scratch pattern of diamonds. (B) With 290 amp per sq in., electrolytic assistance for ½ hr. 500X

SURFACE ROUGHNESS AND APPEARANCE

Table II shows a comparison of the surface roughness of tools ground under the four conditions.

These values were obtained with the carbide held against the grinding wheel at a constant pressure.

Surface roughness measurements were obtained by means of a profilometer at the end of each one-half hour of grinding.

EDGE EROSION

The tool illustrated in the photomicrograph was ⅛ by ½ inch and required less than 1 minute to grind. Rate of carbide removed was 0.0036 cu. in. per minute, and the surface finish produced was 5 to 7 mu in. rms.

It is apparent that no edge erosion occurred under these grinding conditions. During the regular experimental tests, however, when the carbide blanks were ground for one-half hour at a time, the tools showed a definite erosion at the edge of the tool.

However, edge erosion is a function of grinding time. With a short grinding time, edge erosion is avoided.

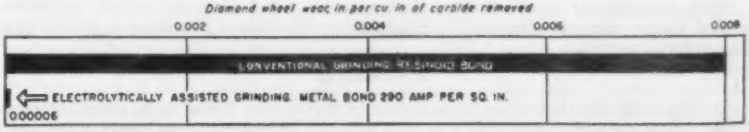
POWER

The amount of power consumed in grinding is an indication of grinding wheel action, and reflects freedom of cut and uniformity of wheel performance during its life.

Inasmuch as the power input to the spindle motor was only half that required for conventional grinding, it is evident that in electrolytic grinding the grinding wheel is free cutting and is not forced beyond its capacity.

The latter observation is particularly true, since in overall performance, the electrically assisted grinding wheel performed considerably more work—in terms of amount of carbide removed and cutting rate—with substantially less power than conventional grinding.

In addition to the power requirements of the grinding wheel spindle, however, the electrolytic process also needs power to assist the wheel in the grinding operation. To supply a current density of 290 amperes per square inch, 0.84 horsepower was required. This brings the total power consumed to 0.98 horsepower which is approximately two and one-half times the power that is required in conventional grinding. (See table II.)



COMPARISON OF DIAMOND-WHEEL wear when grinding tungsten carbide under identical conditions of test. The metal-bond electrolytically assisted diamond-wheel shows a wheel wear of 0.00006 in. per cu in. of carbide removed. This is less than 1% of that obtained with the resinoid-bond wheel, which showed a wheel wear of 0.008 in. per cu in. of carbide removed

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TABLE II

	Electrolytic		Conventional	
	Metal bond D60-N100-M		Resinoid bond D100-N100-BR	Metal bond D60-N100-N
Current density—amperes per square inch	290	153	None	None
Curve	A	B	C	D
Time of test—hour	40	8	20	8
Total carbide removed—cubic inch	8.614	0.936	0.805	0.143
Average cutting rate—cubic inch per minute X 1,000	3.58	1.94	0.67	0.29
Average surface roughness—mu in. rms	14	11	6.0	6.0
Power consumed in grinding—horsepower	0.14	0.20	0.40	0.40
Power consumed for electrolytic assistance—horsepower	0.84			
Total power consumed—horsepower	0.98		0.40	0.40
Wheel wear per cubic inch carbide removed—in	0.00006		0.008	

Equipment: Model X 266 Hammond electrolytic carbide tool grinder, Model 75C selenium rectifier—Input wired for 440 volts, 60 cycle, 3 phase, output 0–18V, 75 amperes, dc. Spindle speed 2600 r. p. m.; wheel speed 4084 sfpm; wheel size 6x¾x1¼ inch, metal-bond type DS 20080. Contact pressure 43 p. s. i. Traverse 30 cycles per minute. Length of stroke 25/32 inch. Electrolyte 5 percent solution sodium nitrite.

SPACING BETWEEN WORKPIECE AND WHEEL

Consideration was given to the distance between the grinding wheel bond and workpiece (i. e., the protrusion of diamonds from the band). Too great a spacing will obviate the electrolytic effect, and too small a spacing may increase current density beyond a usable range and may cause shorting of the electrical circuit.

Space measurements were made on a polarizing microscope, using oblique illumination to determine the distance the diamonds protruded from the bond. The difference in elevation of the diamond was measured by focusing on the upper surface of the diamond and also on the adjacent surface of the matrix, and reading the distance between them.

This method is not precise because it is not always possible to focus directly on the top of the diamond. It did, however, permit an evaluation of the need for a definite spacing between the workpiece and wheel.

The average mean protrusion of the diamonds, based on 15 readings taken on the outer periphery of a wheel and 15 readings taken on the inner periphery, was 0.0023 inch.

The significance is conclusive, that a metal bond diamond wheel, manufactured under current commercial production conditions, produces a substantial electrolytic assist.

ELECTROLYTE

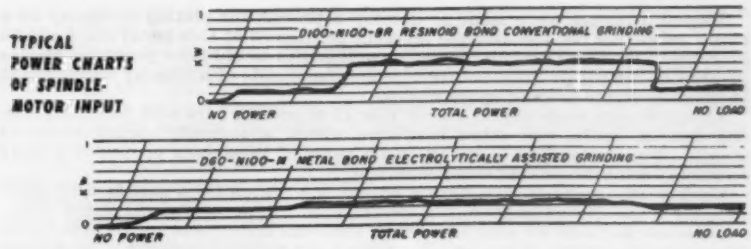
A 5 percent solution of sodium nitrite in water was found to be most satisfactory for electrolytic grinding. It was applied at the point of contact between grinding wheel and workpiece, at the rate of 1 gallon every 21½ minutes. A distinct advantage of the sodium-nitrite solution is that it minimizes corrosion.

The solution performed well for 13½ hours of grinding, although it became progressively contaminated and filled the wheel with a soft deposit. This filling caused the cutting rate to decrease, as evidenced by the dropoff in curve A. Brushing the wheel with a stiff scrubbing brush after 13½ hours restored the cutting rate to its original value and did not consume any diamonds (see point "a" on curve A).

NONDIAMOND WHEELS

The use of nondiamond grinding wheels for electrolytic grinding was also explored.

Preliminary studies were conducted with aluminum oxide and silicon carbide grain in 16 grit and 60 grit. The initial tests were not successful. It is intended to continue this investigation with grinding wheels made under different manufacturing techniques.



American Machinist • September 28, 1953

THE UDYLITE CORP.

GENTLEMEN: I have been asked to describe research and development work in connection with alternates, replacements, and substitutes for, as well as synthesis of, critical materials used in the electroplating industry.

The description will be brief for the simple reason that in spite of a very considerable amount of work in a number of laboratories, and extensive attempts to translate the results of this work into pilot plant and production operations, the final results have been far from satisfactory.

Our principal problem in times of national emergency is the availability of such critical metals as nickel, cadmium, tin, copper, and to a lesser extent, zinc. Lead too is usually in short supply, but is used in plating in much smaller quantities than the other metals mentioned. When these metals are in short supply, their chemical salts with which plating solutions are prepared and maintained are equally difficult to obtain.

Nickel, which is very high on the list of critical materials, is by far the most serious problem in the electroplating industry. It is a metal which is unusually resistant to corrosion, and is applied by electrodeposition in films, varying in thickness from a few tenths of a mil to 2 mils on iron, steel, zinc, copper and brass to protect and beautify a wide variety of articles. The term "chrome plate" used so commonly is a misleading one. In most cases an extremely thin chromium deposit (0.01 mil) is applied over a more substantial coating of nickel for the prevention of tarnishing and scratching. Such chromium deposits are valueless for protection against corrosion when applied directly on a steel or nonferrous basis metal.

Nickel plate depends to a great extent on its thickness for its protective value, and the poor quality of much of the automotive hardware manufactured during and since the Korean emergency is directly related to limited supply of nickel, together with specific prohibitions regarding its use. During this emergency, the quantity of nickel available monthly through conventional channels for electroplating civilian goods varied between 10 and 30 percent of the 1949–50 period on which allocations were based. Even now with restrictions on end use removed, the allocations vary between 35 and 50 percent of the same base period, the average being about 40 percent.

A number of substitutes for nickel-chromium plate were used during the Korean emergency. One of these was a copper plate 1 to 2 mils in thickness, to which was subsequently applied 0.01 mils of chromium plate. This combination was worthless for outdoor use unless further protected by a clear synthetic lacquer or enamel, and the final permanence of the combination was entirely dependent on the synthetic coating. This combination was more costly to apply than a copper-nickel-chromium or nickel-chromium deposit, and much less resistant to corrosion and abrasion.

Another combination which was substituted rather widely in finishing items on which the use of nickel was prohibited was a white brass-chromium combination. The white brass was an 85 percent zinc-15 percent copper alloy. It could be plated bright, but the deposit was very brittle, and tended to stress-crack when chromium plated if more than 0.3 mil thick. When exposed to the weather, unsightly white corrosion products of zinc soon bled through the chromium deposit. Attempts to bake a clear synthetic on this combination resulted in further unsightly stress-cracking. In addition to the poor result, the plating process itself was difficult to handle and caused serious operational difficulties.

Bright zinc with a subsequent chromium deposit was tried early in the emergency, but so far it is not possible to deposit chromium bright direct on zinc.

Several attempts were made to develop a process for plating antimony as a nickel substitute but the extreme inherent brittleness of this metal could not be overcome. It is also doubtful if health authorities would have permitted its use because of the highly toxic nature of some compounds of antimony which might be liberated in the processing operations.

Attempts were made during World War II to produce cars with painted bumpers, guards, grills, and other hardware which is normally nickel-chromium plated. The tremendous losses in resale value of these cars precluded similar attempts during the present nickel shortage.

Work is still going on to a limited extent in a search for a satisfactory alternate for nickel-chromium plate, but the probability of success seems rather slight.

Cadmium and zinc are electroplated on steel and nonferrous metals principally for protection against corrosion. They have the unusual property of protecting these basis metals by electrochemical action, rather than dependence on a completely continuous envelope. For this reason the thickness of film is usually low, on the order of 0.1 to 0.5 mil. They can be plated bright, and when protected further by clear lacquers will retain their pleasing appearance for a considerable time if the exposure is mild. Cadmium, although considerably higher in price, has a number of important advantages over zinc. Solderability, resistance to weak acids and alkalis, electrical conductivity and superior resistance to tarnish are a few of these. However, zinc can be satisfactorily substituted for cadmium in a wide variety of electroplating applications, and this is being done, to such an extent that cadmium is currently in excess supply. However, future shortage of cadmium is predicted by the Bureau of Mines. The use of chemical surface treatments on zinc deposits makes possible its substitution for cadmium in many applications.

The principal use of tin in electroplating is on thin steel strip subsequently formed into tin cans for food packaging. The savings in tin consumption effected by changing from the old hot-dip methods to electrodeposition during World War II are well known.

While rubber may no longer be considered a critical material, it has been during past emergencies, and the electroplating industry has developed synthetic plastic linings for tanks which are for many uses superior to rubber.

Corrosion-resistant alloys containing high percentages of nickel have been used in contact with acid solutions and vapors. In many instances these alloys have been replaced by mild steel completely enveloped in heavy plastisol type films.

In conclusion, the electroplating industry, which normally employs well in excess of 100,00 people, and produces protective, decorative, and functional coatings having an estimated value of more than $350 million annually, has suffered worse than many industries using critical metals and materials. Attempts to develop satisfactory alternates for the metals used have met with little success. It should be emphasized that because of the thin coatings applied, in no other industry can so little material, spread over so large a surface, achieve such savings of labor and dollars and the protection and preservation of such a vast variety of manufactured articles .

R. B. SALTONSTALL,
Technical Director, the Udylite Corp.

GENERAL AMERICAN TRANSPORTATION CORP.,
PLASTICS DIVISION,
Chicago, Ill., March 17, 1955.

UNITED STATES SENATE,
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D. C.

(Attention: Mr. Jerome S. Adlerman, counsel, Minerals, Materials, and Fuels Economic Subcommittee)

DEAR MR. ADLERMAN: Your letter of March 2 has been referred to me for answer.

I am extremely pleased that a Government group is studying the utilization of plastic fuselages in planes and guided missiles, as well as plastics in other elements of such devices. My full answer to your letter will be forwarded in a few day when it is completed.

In the meantime I am enclosing with this brief discussion a reprint of an article describing an Air Force seat pan for a survival kit. We had an opportunity in April 1951 to submit prices and a sample of this item due to a sudden shortage of magnesium and steel, the approved materials for the product. The ejection force requirement was 40 G's and we easily passed this test. We pro-

duced about 50,000 plastic seats, and other procurement boosted the plastic usage to about 70,000 seats.

We reduced the cost from the metal price of $15 each to first $6.43, then to $4.67 each. All together the Air Force budget was reduced by approximately $640,000 for this item by our plastics engineering. Our shock tests successfully went to 70 G's without damage, or 175 percent of maximum design requirement. In addition, we reduced the weight of the item by 10 to 15 percent and eliminated the critical metals entirely.

Plastics in this high-stress application did an exceptional job on all counts—performance, economy, and availability.

There are many, many places where specific types of reinforced plastics are a logical material for aeronautical construction. These include:

1. Jato bottles and closures.
2. Rocket booster bottles and closures.
3. Fuselages, primary.
   - (*a*) Target planes.
   - (*b*) Observation planes.
   - (*c*) Specific missiles.
   - (*d*) Miscellaneous.
4. Wings and control surfaces in combination with metals.
   - (*a*) Target planes.
   - (*b*) Observation planes.
   - (*c*) Specific missiles.
   - (*d*) Jet fighters.
5. Hatches and covers, tank: All types of aircraft.
6. Radomes, radar reflectors.
7. Interior paneling, flooring.

Likewise there are many places where plastics cannot be considered, based on present missile engineering methods. Principally these situations revolve about the extreme temperature problems.

To date we do not design plastics parts requiring long-term exposure to temperatures above the present 600° to 700° F. barrier, due to thermal decomposition and softening of the current organic laminating resins. Of course, commercially available reinforcements for plastics can withstand temperatures in the 1,000° to 1,500° F. range, while experimental refractory fibers are known with melting points to 3,000° F.

We expect the reinforced plastics trend to turn more and more toward ceramic-organic types of resins or binders for refractory types of fiber or film reinforcement. Thus heat resistance in the 2,000° F. range may someday be achieved in structural plastics.

Obviously, there is no solid substance known to man, including nickel-iron and silicate meteorites, which can pentrate the earth's atmosphere at 18,000 to 75,000 miles per hour and survive the frictional aerodynamic heating experienced. Accordingly, aircraft and missile designers must rely on clever engineering and tactics to fashion airframes capable of attaining their aeronautical goals; heat resistance of structural materials, metal or plastic, will not alone solve these problems.

Further details will follow.

Sincerely yours,

E. F. BUSHMAN,
Technical Director, Reinforced Plastic Department.

[Reprinted from Modern Plastics, December 1952, New York 22, N. Y.]

REINFORCING REINFORCED PLASTICS

(By Edwin F. Bushman[1])

The high unidirectional strengths and moduli of fibrous glass polyester fishing rods have now been applied to matched die molding of glass fabrics and preforms by the reinforced plastics department, General American Transportation Corp. The use of specially manufactured glass cables has enabled this firm to engineer unidirectional strength into preform products with locally oriented tensile

[1] Technical director, reinforced plastic Department, General American Transportation Corp., Chicako, Ill.

strengths and flexural moduli approximating those of reinforced plastics fishing rods.

These cables can be designed into parts across areas of exceptionally high stress, thus permitting designers to reduce the main wall sections of structures to the minimum thicknesses required for ordinary wear and structural unity. In this fashion the weight of heavily stressed products can be kept to a minimum, without the use of troublesome metal reinforcements or difficult assemblies.

In experimentally developing a highly stressed, lightweight parachute "explosion" seat for the Air Force, General American engineers concluded that unidirectional reinforcement extending entirely across the area of maximum flexure would prevent rupture and failure of the product.

Drop testing proved the calculations to be correct, and production methods of achieving such unidirectional reinforcing were studied. A large number of techniques were tested experimentally. These included sewing a ⅜-inch diameter bundle of fibrous glass roving within strips of glass cloth; also impregnating the roving bundles with various types of polyester and alkyd resins, and twisting to keep the bundle together. However, best handling properties were found to be achieved by drawing the ⅜-inch roving bundle within a length of ⅜-inch diameter glass braided sleeving, as in figure 1.

Upon completion of this experimental investigation, a contract was awarded to Insulation Manufacturers Corp., Chicago, for braiding production quantities of this special glass cable in the Electra Insulation Co. plant, Woodside, Long Island, N. Y. Several experimental runs were made, with each sample braid being tested for its impregnating and molding efficiency in General American's reinforced plastics plant. On the completion of tests a production setup was made in the Electra plant, as shown in figure 2. Here fibrous glass roving is drawn simultaneously from 40 balls of roving. This loose assembly of approximately 490,000 glass filaments is drawn from below a 56 spindle New England Butt Co. braiding machine. The fibers are drawn through a collimating tube, then condensed to ⅜-inch diameter by a small steel die. As shown in the illustration, one glass textile fiber strand from each of the braiding spools is drawn per standard brading procedure, through the ⅜-inch die and woven over and around the roving bundle.

In molding parachute seats in the General American plant, 15-inch lengths of this special glass cable are preimpregnated with pigmented polyester resins, and delivered to the molding press for use. Placement of these unidirectional cables in the molded part has been done in several different ways, one of which is illustrated in figure 3. As shown, the impregnated cable is positioned in a recess in the steel mold by pressing it on to sharp pointed steel pins which are located along the axis of the desired reinforcement. Satisfactory results have also been obtained with desired time savings by locating these impregnated cables in the preform itself prior to placing. As shown in figure 4, the fibrous glass preform is positioned over the unidirectional cables on the punch of the steel mold. Following impregnation and molding, as illustrated, the part is removed from the press. Figure 5 shows location of the unidirectional glass cable along the two underside corners of the "explosion" seat, in the area of most severe flexing.

In this fashion homogeneous strength can be molded into a part with a wall section of as low as 0.060 to 0.070 inch, with strategically placed unidirectional sections 3 to 5 times greater in strength, in thicknesses as great as one-half inch. Satisfactory explosion and drop testing resistance of the molded seat to shocks exceeding 40 G's has been achieved, while keeping the weight of the molded part at 4 to 8 ounces below the maximum allowed weight of 2½ pounds.

Research for Replacement of Tin in the Manufacture of Metal Cans by American Can Co.

INTRODUCTION

The tin can is an important element in the American way of life and indispensable to the Armed Forces. The manufacture of cans is threatened by the complete lack of an adequate domestic supply of tin to guard national security and health. This report is submitted to describe the requirements of the can-making industry, the results of tin conservation efforts during and since World War II, and the American Can Co.'s operation-survival program for the ulti-

mate complete elimination of the dependency of the can manufacturing industry on tin.

The metal container in the American economy

Since the first metal cans were introduced into the United States in the 1820's, cans have played, decade by decade, an increasingly important role in the American way of life.

The first cans were manufactured by hand at canneries during the winter months. Gradually the genius of inventors began to mechanize can-making operations. By the turn of the century automatic lines could manufacture 5,000 to 6,000 cans an hour. With increasing speeds came lower-cost cans. More and more products began to be available in cans throughout the entire year. Canned foods soon changed from luxuries to staples, which form the bulk of purchases by the lower-income groups.

Besides foods, a large group of so-called nonfoods have, during the past 50 years, become available to the American consumer in metal cans. These are principally industrial products, useful on the farm and in the home and factory to increase the convenience and safety of the American way of life.

The canning of new products, both food and nonfood, and the trend from bulk to individual packaging, has, since 1900, further increased the demand for cans. Year by year can production increased, almost without exception. Representative annual production figures over the past half century are given in table 1 of the appendix to this report. A steady growth is shown from an estimated 2 billion cans in 1900 to over 35 billion in 1953.

Nutrition.—Increasing consumption of canned food products has had a very important beneficial influence upon the peacetime nutrition of the American public. A comparison of the average dietary in 1909 with that of the present shows the striking increases in the consumption of canned juices, fruits and vegetables that have taken place. The present dietary shows significant increases in the intake of vitamins A, B_1, B_2, niacin, C, and calcium. Furthermore, extending the availability of fruits and vegetables from the Biblical "season thereof" to a year-round basis, leveled out the vitamin intake to provide an improved diet throughout the year.

A comprehensive study of the nutritive content of canned foods has been sponsored jointly by the National Canners Association and Can Manufacturers Institute. Data obtained at reliable academic laboratories at a cost of more than $400,000 enable nutritionists to prescribe adequate diets and assist the canners in preserving the natural nutrients through scientific canning procedures.

Benefits to the farmer and rural communities.—The canning industry has been of great benefit to the farmer. Canning permits the marketing of large quantities of perishable crops in sparsely populated areas for consumption out of season in heavily populated areas. The canning industry has assisted the farmer by the development of suitable varieties for canning crops and the dissemination of information on scientific agricultural methods. Employment at local canneries is an important factor in the economic stability of many rural communities.

War and national defense.—The preservation of foods in cans benefited not only the civilian population, but the armed services as well. In this connection it is well to recall that it was because Napoleon Bonaparte's armies suffered from hunger due to a meager diet of smoked fish, salt meat, and hard bread that the French Directory offered a prize to anyone who could develop a method of preserving fresh foods. Nicolas Appert accepted the challenge and his discovery was the canning process.

In each of the wars since Appert's time in which the United States has participated, the quartermasters have been increasingly dependent upon metal containers to supply the Armed Forces in both garrison and field. This was true of the recent Korean incident. Speaking in 1951 of the disposition of the military ration dollar, the Quartermaster General of the Army said, "When refrigeration is unavailable or limited as in overseas combat areas, the entire ration dollar is spent for nonperishable food, or, one might say, 'the dollar goes into the can'."

During World War II, experimental shipments were made of items in substitute containers, principally made of fiber materials. By and large, the results were not satisfactory as compared to their metal counterparts, long before the war was over, the Quartermaster Corps was openly declaring "no other container protects like the metal can."

Thus the humble can has become increasingly important to both civilians and the members of the armed services. It can be conservatively said that the can is as essential to the American way of life as the incandescent lamp. It is, therefore, the obligation of Government, as exemplified by this committee, to be sure that the necessary production of these essential containers is insured.

Annual requirements of raw materials for can manufacture

The principal raw materials used in the fabrication of tin cans are: steel, tin, synthetic rubber, resins, and drying oils. Tinplate is made by the application of a thin coating of tin to steel plate. Some tin is also used in soldering the can side seams. Rubber is used in sealing compound for the crimped and seams. The resins and drying oils may be used in protective and decorative enamel coatings on both interior and exterior surfaces of the cans.

Requirements for steel.—In 1953, can manufacturers fabricated 4,003,692 tons of sheet metals into cans. This tonnage was 5 percent of the total 1953 finished steel production of 81,482,100 tons. Shipments to can manufacturers in 1953 and several prior years are shown in table 2 of the appendix to this report.

Requirements for tin.—Consumption of tin in the can manufacturing industry in 1952 is estimated at 23,190 long tons, of which 21,790 long tons were required for the manufacture of tinplate and 1,400 long tons for the manufacture of solders. The tin used in the industry during 1952 and several prior years is shown in table 3 of the appendix.

Other materials.—Several million pounds of synthetic rubber were used in 1953 for the formulation of sealing compounds employed in can closure.

The resins and drying oils used in the preparation of inside and outside coatings for cans approximated 80 million pounds in 1953. The pounds of coatings required per ton of steel has increased as the amount of tin used has decreased.

Tin, the critical raw material

Although iron ore, coal, and limestone for the making of steel, synthetic rubber, and drying oils and resins can be produced in abundance on this continent, as previously indicated, tin cannot. There are no sources of tin of commercial significance in North America. All of this country's tin must be imported over long sealanes, and well over half of the world's production is in lands that lie in the immediate path of the calculated Communist aggression.

Production of tin during the last decade is shown in table 4 of the appendix and the sources of United States' imports during 1950–52 are shown in table 5. Bolivia is the only significant source in the Western Hemisphere and her production is not adequate for United States' requirements.

The unique properties of tin which render it an ideal coating material for metal cans

Tinplate has been called a successful marriage combining the protective properties of tin with the strength of steel. The tin coating provides an attractive appearance and also facilitates soldering cans at high speeds. Furthermore, the thin films of tin, varying with the weight of the tin coating from fifteen to ninety millionths of an inch thick, serve as excellent lubricants, reducing wear of can-making equipment during the fabrication and assembly of container parts.

When tinplate is employed for can manufacture, the tin coating protects the steel from both external and internal corrosion. On the outside of the can, the tin which covers the steel prevents the rusting of the tin plate under most of the storage conditions encountered in the domestic distribution of canned foods. Yet, if exposed directly to the elements, tinplate disintegrates in a relatively short time.

Tin is essentially inert to many food and nonfood products. Under the conditions inside of a food can (absence of air) tin electrochemically protects the steel from corrosion. It is this unexpected effect, which would not be predicted by reference to chemical textbooks, which really makes practical the canning of many foods. Furthermore, the slow rate at which tin sacrificially goes into solution, and the innocuousness of its corrosion products, make tin unique among metals. No other metal has been found which has all the characteristics of tin.

Results of tin conservation

Our company as a major can maker was the first to be interested in tin conservation well before the beginning of World War II and leadership in this activity was assumed by Dr. R. H. Lueck, our general manager of research.

In 1937, a pilot line was constructed by one of the steel companies for the manufacture of tinplate by the electrolytic process instead of hot-dip tinning. Experi-

mental packs by our company were made of various foods in cans made of plain and enameled electrolytic plate. The results of these experiments served as a basis for commercial use of electrolytic tinplate early in World War II, after the disaster at Pearl Harbor.

With the start of hostilities in Europe in 1939, attention was turned toward the development of a chemically treated steel which could be used to make cans for low acid products. This work, initiated by our company, led to bonderized steel which was later used successfully on can ends for nonacid food products such as: peas, corn, succotash, and others.

By July of 1941, the technical committee for tin conservation of the Can Manufacturers Institute had projected the use of untinned steel, chemically treated steel, electrolytic plate, and hot-dipped plate bearing a lighter coating of tin, for the nonprocessed food and nonfood household and industrial items. This was some 5 months before Pearl Harbor.

With the entry of the United States into the war later in 1941, the above committee suggested the manner in which these plates could be safely used for processed foods. Under the guidance of Dr. Lueck, it then developed a four-stage program of increasing tin conservation through the use of these plates and furnished the War Production Board with statistics on the amount of tin that would be required for cans for each commodity in each stage of the program. These recommendations served as the basis for WPB Order M–81.

To carry through the program, the steel producers installed electrolytic tinning and bonderizing lines sufficient to supply the amount of alternate plates that the canmakers had indicated they would need, and the canmakers modified their facilities to permit use of the new plates.

The results.—The program was strikingly successful as far as tin conservation was concerned. The alternate plates performed so well that there has been no significant return to the use of more heavily coated hot-dipped plate now that more tin is available. In fact, use of electrolytic plate bearing even lighter coatings of tin was extended in the postwar period, and, as table 6 indicates, the tin used per ton of steel has continued to decrease. Our company has had a large share in accomplishing this saving.

Tin conservation has greatly reduced the expenditure for the tin imported into this country. If the same tin requirement per ton had prevailed in 1952 as in 1941, approximately twice as much tin would have been required. The Can Manufacturers Institute has presented the figures shown in table 7 for the monetary savings accomplished through tin conservation. The data refer to all tin mill products, not only those shipped to can manufacturers and show cumulative savings through 1952 in excess of half a billion dollars.

The necessity for further reducing dependency upon tin

The President's Materials Policy Commission in June 1952 indicated that the tin reserves of the free world have been estimated at 5 million long tons of metal in ore. It states, "Nevertheless, it seems clear that 'known' reserves are of the order of 30 times the 1950 rate of production. Thus, if the 1950 rate is to be maintained during the next 25 years, much less increased by 18 percent, new reserves will have to be discovered." However, even more significant are its words, "The major problem affecting the future tin supply arises from the danger that the flow of tin may be interrupted by war or political disruption."

Twice before, in 1942 and 1950, Government tin restrictive orders have been issued which have seriously disrupted can manufacturers' operations in spite of the existence of large stockpiles of tin, and in many instances the lack of containers has forced packers to curtail operations. Today the strategic stockpile is said to be larger than ever before, estimated by Tin to be of the order of 200,000 long tons, enough to supply this country's requirements for 4 years. But this stockpile is only short-term insurance at best. To insure a long-term supply of metal cans, can manufacturers must learn how further to reduce their dependency upon tin.

Since 1940, steel production capacity has been increased approximately 50 percent, from 81,619,000 tons to 117,547,470 tons. Steel capacity is now such that, in the event of war, manufacture of cans need not be curtailed from a lack of steel. Consequently, the development of satisfactory alternates for tin should eliminate the need for restriction of metal can manufacture and use during wartime emergency.

American Can's operation survival program

In a program designated "Operation Survival," the American Can Co. is conducting research with the ultimate objective of complete elimination of the

use of tin in the manufacture of metal cans. Thus far, it pursues this difficult but essential objective without the aid of competitive or Government research assistance.

In pursuing this objective during a peacetime economy, tin-free containers must be competitive with those of tinplate on the basis of appearance, performance, and cost in a free and open market. This is a difficult and long-range task. By so doing, however, our company is automatically preparing itself to cope with those times of national emergency when some sacrifice in one or more of these qualities is required by the necessity for conserving strategic materials. Developments coming out of the Operation Survival program will minimize these quality sacrifices.

The most promising alternates for tinplate now under advanced study are in several broad categories of materials or combination of materials. The major emphasis has been placed on the replacement of the tin coating by organic coatings or by combinations of organic coatings plus inorganic coatings (chemical treatments) on the steel surfaces. All of these materials are available in the United States. Alternate metallic coatings on steel are also under study, the two of most immediate promise being aluminum and nickel (use of the latter would be dependent on increased production capacity and its official assignment from decorative to can-making uses). The only alternate material under active study which does not involve steel is aluminum alloy plate.

Type of research projects involved in the program.—Among the several categories into which the technical problems fall, probably the most important is the sealing of the side seam of the body. Steel is much more difficult to solder than tinplate, and in the present state of the container manufacturing art steelplate cannot be soldered without great sacrifices in both manufacturing efficiency and ultimate container quality. This problem is being attacked in three different ways:

1. Application of a metal coating on the margin areas of the steel to facilitate soldering with tin-free or low-tin solder.
2. Electric welding.
3. The replacement of metallic solders by organic cements of high bonding strength and sealing efficiency.

Another field of major endeavor is the development of new organic coatings for the special purpose of protecting steel surfaces. The corrosion hazards both inside and outside of the container walls are somewhat unique and require organic coating materials generally quite different from conventional enamels and lacquers.

The efficiency of protection by organic coatings alone can be greatly enhanced by chemical pretreatment of the steel surface (bonderizing). This well-known effect needs research both to improve its effectiveness and lower its cost, which is now too high to be competitive with tinplate.

Historically, production of untinned steel sheets for containers has been such a small fraction of the total tin-mill output that it has not warranted serious technological study. Research dedicated to modifying manufacturing practices to improve the corrosion resistance of steel sheets is now in progress and gives promise of yielding an improved product. It is hoped that such steel sheets may be adequately protected by special can enamels without the benefit of chemical pretreatment.

Operation Survival not only includes all departments of the American Can Co., but coordinates the enthusiastic cooperative research efforts of a number of material suppliers and other technical concerns.

TABLE 1.—*Estimated number of No. 2 cans which might have been produced from the amount of steel consumed in canmaking*

	Billion		*Billion*
1953	35½	1940	19
1952	33½	1930	12
1951	33½	1920	10
1950	34	1910	5
1945	21	1900	2

Source: 1940 and subsequent years from Can Manufacturers Institute. Previous years estimated from tinplate production.

TABLE 2.—*Shipments of plate by tin mills for the manufacture of cans*

	Tons of plate		Tons of plate
1953	4,003,692	1947	2,956,116
1952	3,842,170	1946	2,759,519
1951	3,804,551	1945	2,441,574
1950	3,893,384	1944	2,071,594
1949	3,276,918	1943	1,684,468
1948	3,245,145		

Source: Data from Can Manufacturers Institute.

TABLE 3.—*Estimated can manufacturers' consumption of tin*

[Long tons]

	Tinplate [1]	Solder	Total		Tinplate [1]	Solder	Total
1952	21,790	1,400	23,190	1946	20,330	950	21,280
1951	21,320	1,400	22,720	1945	18,180	1,250	19,430
1950	27,260	1,550	28,810	1944	16,330	1,200	17,530
1949	22,790	1,000	23,790	1943	14,290	1,500	15,790
1948	21,410	1,200	22,610	1942	17,890	2,000	19,890
1947	20,430	1,225	21,655				

[1] Includes some terne plate (lead-tin alloy coating) for nonfood use.

Source: Data from Can Manufacturers Institute.

TABLE 4.—*Tin production*

[Long tons of metallic tin]

	World	Malaya	Nigeria	Bolivia	Indonesia	Belgian Congo	Thai	Others
1953	175,500	56,255	8,215	34,836	33,753	17,153	10,124	15,200
1952	170,500	56,838	8,315	31,950	35,003	13,798	9,479	15,500
1951	167,500	57,167	8,539	33,134	30,986	13,669	9,502	14,500
1950	166,000	57,537	8,258	21,213	32,102	13,464	10,364	13,200
1949	162,000	54,910	8,823	34,114	29,033	13,760	7,815	13,300
1948	151,500	44,815	9,237	37,336	30,613	12,859	4,240	12,600
1947	112,500	27,026	9,133	33,266	15,936	12,411	1,401	13,100
1946	89,000	8,432	10,333	37,618	6,423	14,241	1,056	10,800
1945	88,000	3,152	11,224	42,486	1,050	17,049	1,775	11,100
1944	100,000	9,309	12,512	38,720	7,008	16,857	3,296	11,600
1943	139,000	26,000	12,661	40,313	19,085	17,025	5,840	17,900
1942	121,000	15,748	12,403	38,292	9,898	15,797	7,833	21,000

Source: From Tin, September 1954.

TABLE 5.—*United States imports of tin in metal and tin concentrates*

[Long tons]

	1950	1951	1952		1950	1951	1952
Malaya	53,699	6,986	45,891	Thai	2,957	3,114	4,891
Indonesia	6,925	11,684	6,757	Others	27,582	20,507	34,303
Bolivia	14,602	13,085	12,639				
Belgian Congo	3,032	2,500	2,467	Total	108,797	57,876	100,948

Source: From Materials Survey, U. S. Department of Commerce, June 1953.

TABLE 6.—*Steel and tin consumption in canmaking industry*

	Steel, tons	Tin, long tons (excluding solder)	Pounds of tin per ton of steel
1941	2,844,678	32,330	25.4
1942	2,043,095	17,890	19.5
1943	1,684,468	14,290	19.0
1944	2,071,594	16,330	17.6
1945	2,441,574	18,180	16.7
1946	2,759,519	20,330	16.5
1947	2,956,116	20,430	14.8
1948	3,245,145	21,410	15.3
1949	3,276,918	22,790	15.6
1950	3,893,384	27,260	15.7
1951	3,804,551	21,320	12.6
1952	3,842,170	21,790	12.8

Source: Data from Can Manufacturers Institute.

TABLE 7.—*Tin mill products—Tin conservation and monetary savings*

Year	Tin mill products, total production in United States	Tin, total amount used	Estimated		
			Tin coating, average per base box	Saving over prewar rate of use	Cumulative dollar value of saving
	Short tons	*Long tons*	*Pounds*	*Long tons*	
1941	4,100,953	46,900	1.210	3,874	$3,905,000
1942	3,337,947	29,404	.936	11,750	17,618,000
1943	2,595,772	22,160	.899	10,132	29,760,000
1944	3,241,642	25,708	.840	14,384	46,933,000
1945	3,581,073	26,821	.794	17,431	67,744,000
1946	3,585,986	26,573	.767	18,811	91,088,000
1947	4,528,983	31,481	.721	25,717	131,124,000
1948	4,847,370	32,175	.686	29,266	195,434,000
1949	4,321,417	30,243	.725	24,403	249,987,000
1950	5,158,414	36,332	.736	28,335	311,299,000
1951	5,573,775	31,289	.586	38,700	427,463,000
1952	4,913,516	27,896	.593	33,729	518,127,000

Source: From Can Manufacturers Institute.

(Whereupon, at 6:25 p. m., the hearing was recessed until 9 a. m., Friday, November 19, 1954.)

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